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Editor's Corner

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NASA's Earth Science Division is off to a roaring start in 2015! Two new Earth Science missions have already launched, and a third joint mission with NOAA and the U.S. Air Force, which includes two Earth observing instruments that will view the Earth from a never-before-seen perspective, is planned for early February.

A SpaceX Dragon spacecraft successfully carried the Cloud Aerosol Transport System (CATS) payload (along with other cargo) to the International Space Station onboard a Falcon 9 rocket launched from Cape Canaveral Air Force Station in Florida at 4:47 AM EST on January 10, 2015. On January 22, CATS was installed on the space station's Japanese Experiment Module – Exposed Facility (JEM-EF)—the first NASA-developed payload to ever fly on the JEM-EF. Systems have been powered up and preliminary indications are that everything is functioning nominally. The plan moving forward is to work through turn-on/check-out sequences, with a goal of receiving first science data sometime around February 1. Designed to operate for at least six months—with a goal of three years, and the possibility to operate as long as five years—CATS will provide vertical profiles of cloud and aerosol properties at three wavelengths (1064, 532, and 355 nanometers). CATS will serve as a "bridge" between CALIPSO and ESA's EarthCARE mission, helping to extend the CALIPSO data record for continuity of lidar climate observations. More information about CATS is at *cats.gsfc.nasa.gov*.

On January 31, 2015, NASA successfully launched the Soil Moisture Active Passive (SMAP) spacecraft from Vandenberg Air Force Base in California, aboard a United Launch Alliance Delta II *7320-10C*. The SMAP mission is NASA's first Earth-observing satellite mission designed to collect continuous global observations of

continued on page 2

This long exposure photograph shows NASA's SMAP observatory as it successfully launched from Vandenberg Air Force Base in California at 9:22 AM EST on Saturday, January 31. **Image credit:** NASA/ Bill Ingalls

In This Issue

Editor's Corner Front Cover

Feature Articles

15@15: 15 Things Terra has Taught Us in Its 15 Years in Orbit 4

SMAP: Mapping Soil Moisture and Freeze/Thaw State from Space 14

NASA's Hyperwall: Around the World in 2014 20

Meeting Summaries

The SMAP Early Adopters Program and the Impact on Prelaunch Research 24

Summary of 2014 GOFC-GOLD Fire Implementation Team Meeting 29

Joint CERES, ScaRaB, and GERB Science Team Meeting 34

NASA Sounder Science Team Meeting 39

Kudos

Congratulations William T. Pecora Award Winners! 41

In the News

NASA's Spaceborne Carbon Counter Maps New Details 42

NASA Satellites Measure Increase of Sun's Energy Absorbed in the Arctic 44

NASA Analysis: 11 Trillion Gallons to Replenish California Drought Losses 45

Snow in the Northeastern U.S. 46

Regular Features

NASA Earth Science in the News 48

NASA Science Mission Directorate – Science Education and Public Outreach Update 50

Science Calendars 51

Reminder: To view newsletter images in color, visit *eospso.nasa.gov/earth-observer-archive.*

surface soil moisture and freeze/thaw state every 2 to 3 days. We feature a full-length article about the mission—beginning on **page 14**—that provides details on instrumentation, spacecraft design, data acquisition, and a discussion about the societal benefits of SMAP data. We also include a summary of the recent activities of the *SMAP Early Adopters Program*—groups and individuals who have a direct or clearly defined need for SMAP-like soil moisture or freeze/thaw data, and who are planning to apply their own resources (e.g., funding, personnel, facilities, etc.) to demonstrate the utility of SMAP data for their particular system or model. Learn more by reading the summary on **page 24** of this issue.

With the successful launch of CATS and SMAP, five NASA Earth Science launches have taken place in the span of twelve months. In addition to the two launches mentioned here, the GPM Core Observatory, OCO-2, and ISS-RapidSCAT missions have all taken to the skies since February 2014. *The Earth Observer* reported on each of these missions extensively during 2014. For an update on OCO-2 science, see the news story on **page 42** of this issue describing recently released global maps of carbon dioxide and solar-induced fluorescence.

Also, in our last issue, we described the joint NOAA–U.S. Air Force–NASA Deep Space Climate Observatory (DSCOVR), which while not classified as an Earth Science mission, has two the Earth-observing instruments onboard: Earth Polychromatic Imaging Camera (EPIC) and National Institute of Standards and Technology Advanced Radiometer (NISTAR)[1]. DSCOVR is now scheduled to launch no earlier than February 8, from Cape Canaveral Air Force Station onboard a SpaceX Falcon 9 rocket. After launch, the spacecraft will travel 1.5 million km (930,000 mi) from Earth, and enter an orbit around the Sun–Earth Lagrange Point (L1). (Based on the current schedule, this would happen on June 5.) Once in position, DSCOVR's two Earth-observing instruments will begin making the first Earth observations ever obtained from that distant vantage point.

Looking toward the future, on November 25, 2014, NASA announced the winners of second Earth Venture Suborbital (EVS-2[2]) AO. According to **Jack Kaye** [NASA Headquarters—Director of Research for the

[1] To learn more about DSCOVR and its Earth-observing instruments, see the Editorial of the November–December 2014 issue of *The Earth Observer*.

[2] *Earth Venture* investigations are regularly solicited, quick-turnaround projects recommended by the National Research Council in 2007, and reported on in the September–October 2010 issue of *The Earth Observer* [**Volume 22, Issue 5**, pp. 15-18]. The first series of five sub-orbital projects (EVS-1, or EV-1) was selected in 2010, has been ongoing over the past few years, and was reported on in the July–August issue of *The Earth Observer* [**Volume 25**, **Issue 4**, pp. 19-32].

Earth Science Division], "these new investigations address a variety of key scientific questions critical to advancing our understanding of how Earth works. These innovative airborne experiments will let us probe inside processes and locations in unprecedented detail that complements what we can do with our fleet of Earth-observing satellites." Congratulations to all the PIs and investigation teams for each of the five new airborne investigations that will tackle climate questions from Africa to the Arctic. To view the suborbital mission details please visit *go.nasa.gov/1H6yR6s*.

As we celebrate new launches, we also recognize the continuing achievements of our existing fleet of Earth science satellites and those who continue to coax new science out of aging hardware. The American Geophysical Union (AGU) Fall Meeting is an opportunity to showcase these accomplishments. As in past years, the NASA Science Program Support Office organized the 2014 AGU exhibit booth on behalf of the Science Mission Directorate. The *Hyperwall*—a high-resolution video wall—was the centerpiece of the exhibit, supplemented by other activities. Many of the presentations at the booth focused on the achievements of one or more of our Earth science missions. In a 37-day span to close out 2014, staff from the support office also traveled to Sydney, Australia to exhibit at the World Parks Congress conference—held once a decade—and Lima, Peru to support the 20th Conference of Parties (COP) to the United Nations Framework Convection on Climate Change (UNFCC) conference. Please turn to **page 20** to read how the Hyperwall was used in these settings to personally communicate NASA Science face-to-face.

During AGU there were also two special sessions organized in conjunction with milestone achievements for two of the EOS "flagship" missions—Terra and Aura. On December 18, 2014, Terra celebrated the fifteenth anniversary of its launch, and there was a session held on December 19, titled "Terra: 15 Years as the Earth Observing System Flagship," consisting of both an oral and poster session. All of the instruments were represented during the poster session with a range of topics including outreach activities, data quality and sensor calibration, surface change, and climate studies. The oral session was dedicated to talks by each of the instrument leads, an overview of the platform, an example of Terra-sensor intercomparisons, and concluding with an overview of Terra data applications. Many of the topics raised during the session are included as part of the article, "15@15: 15 Things Terra has Taught Us in its 15 Years in Orbit," that appears on **page 4** of this issue.

In addition, July 15, 2014 marked the tenth anniversary of the launch of Aura and there was an AGU special session titled, "Observations from Aura: An Integrated Observatory of Atmospheric Composition," held on December 17. Both the oral presentations and posters presented new results from each of Aura's three major themes: ozone depletion, air quality, and climate—similar to those that appear in the feature article published in our last issue [**Volume 26, Issue 6**, pp. 4-17] titled "Aura Celebrates Ten Years in Orbit."

In other news, the CloudSat-CALIPSO Science Team convened November 1-3, 2014, in Alexandria, VA. Attendees represented NASA Centers, universities, and international partners. These two missions have worked closely together from the start, having launched together in 2006 to fly in formation with each other as part of the A-Train to study the three-dimensional structure of clouds and aerosols. One significant topic of discussion was orbital scenarios to accommodate CALIPSO's fuel limitations. Participants agreed that CALIPSO should participate in A-Train inclination-adjustment campaigns through 2017, and then begin to gradually drift eastward across the MODIS swath, providing a sampling of MODIS look-angles—which was an original goal of the CALIPSO ESSP proposal. It was also agreed that formation-flying of the CloudSat and CALIPSO satellites to provide joint radar/lidar data products has proven of such high scientific benefit that it should continue as long as possible. Consequently, CloudSat will "follow" CALIPSO on its eastward drift after the 2017 A-Train inclination-adjustment campaign.

Abstracts of the oral and poster presentations are available at *stm.dpc.cira.colostate.edu.*

Lastly, **Dong Wu** [NASA's Goddard Space Flight Center (GSFC)] has been selected as Project Scientist for SORCE/TSIS[3]. Wu has been part of GSFC's Climate and Radiation Laboratory since 2011, and prior to that, since 1994, he was with NASA/Jet Propulsion Laboratory's Aerosol and Cloud Group. Wu has worked with numerous Earth science missions/instrument datasets over the years (e.g., CloudSat, MLS, MISR). His interest in sun-Earth connections includes funding from the Living with a Star program. Wu replaces **Bob Cahalan**, who recently retired from GSFC after a distinguished 40-year career at NASA. Congratulations to Wu on his new role, and best wishes to Cahalan in his future endeavors—and many thanks for his leadership on SORCE and TSIS. ■

[3] TSIS is a solar irradiance instrument planned as a follow-on to the Total Irradiance Monitor (TIM) that flies onboard SORCE.

Note: List of undefined acronyms from the *Editor's Corner* and the *Table of Contents* can be found on **page 40**.

feature articles

15@15: 15 Things Terra has Taught Us in Its 15 Years in Orbit

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While Terra has not (yet) broken any records for longevity, it is still operating at near-full capability now nine years beyond its designed six year lifetime, with only slight reductions in its data-gathering capabilities—as described here. The rest of the platform is in fine shape, and scientists and engineers expect it to continue to collect valuable data for almost another decade.

Introduction

Fittingly for NASA's then-nascent Earth Observing System (EOS), the first of what would become three "flagship" satellite missions was named *Terra.* Beginning with the prosaic designation of AM-1—because of its sun-synchronous polar orbit, with a descending-node 10:30 AM equator-crossing time—Terra, launched in December 1999, forged paths of science goals, design, and implementation that subsequent platforms have continued, with wonderful success. While Terra has not (yet) broken any records for longevity, it is still operating at near-full capability now nine years beyond its designed six-year lifetime, with only slight reductions in its data-gathering capabilities—as described here. The rest of the platform is in fine shape, and scientists and engineers expect it to continue to collect valuable data for almost another decade.

Terra's Origins and Mission

In the late 1980s and into the early 1990s, as EOS began to travel the long and difficult road from concept to reality[1], there was as yet no unified plan to explore the phenomena that together make up the Earth system. The concept of studying the Earth as a system of systems was a new paradigm—one that required new ways of exploring these phenomena.

It was clear from early investigations, and often from simple observation, that the Earth was in a constant state of flux, with data that showed that humans could have an effect on such phenomena. Furthermore, the success of pioneering programs such as Nimbus and follow-on missions (e.g., the Upper Atmosphere Research Satellite (UARS), Landsat, the Ocean Topography Experiment (TOPEX)/Poseidon, and the series of Total Ozone Mapping Spectrometer (TOMS) instruments[2]) had shown that satellites could be useful tools for studying Earth-system phenomena. Think, for example, of the historical underpinnings of the formation and causes of the Antarctic ozone "hole" that led to the 1987 Montreal Protocol that banned stratospheric ozone-depleting substances (ODS).

In this light, thousands of scientists, engineers, administrators, and managers worked to bring EOS into being, with plans to begin a systematic exploration of our home planet[3]. The first of the planned series of probes was Terra—an international mission, with major contributions from the U.S., Japan, and Canada.

Terra was to explore the state of and changes in specific phenomena—and interactions between them—in the atmosphere, in and over the ocean, on and over land masses, precipitation as snow and ice, land and sea ice, and Earth's energy budget.

Terra's Manifest

The Terra platform is approximately the size of a small school bus—6.8 m (22.3 ft) long by 3.5 m (11.5 ft) across, weighing just under 5190 kg (11,442 lbs). It orbits Earth at an altitude of 705 km (438 mi) at an inclination of 98.5°. This gives it an orbital period of 99 minutes, for 16 orbits per day. As mentioned earlier, it crosses the equator at 10:30 AM (and also at 10:30 PM). (In contrast, Aqua, the second "flagship" mission, crosses the equator at 1:30 PM (and also at 1:30 AM)—and was originally called PM-1.)

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1 For an excellent compendium on the origins of EOS, download the special "Perspectives on EOS" issue of *The Earth Observer* found at *eospso.gsfc.nasa.gov/earthobserver/new-perspectives-eos*.
2 TOMS flew onboard Nimbus-7 [1978-93], the Russian Meteor-*3M* satellite [1991-94], the Japanese Advanced Earth Observing Satellite (ADEOS) [1996-97], and Earth Probe [1996-2006]; QuikTOMS also carried a TOMS instrument onboard, but failed to reach orbit in 2001.
3 For more information on the process, refer to the March-April 2014 issue of T*he Earth Observer* [**Volume 26**, **Issue 2**, pp. 4-13].

To meet the scientific mission requirements, Terra was outfitted with five instruments designed to explore phenomena at or near Earth's surface. These are the:

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provided by the Japan Aerospace Exploration Agency (JAXA);
- Clouds and Earth's Radiant Energy System (CERES), provided by NASA;
- Multi-angle Imaging Spectroradiometer (MISR), provided by NASA;
- Moderate Resolution Imaging Spectroradiometer (MODIS), provided by NASA; and
- Measurements of Pollution in the Troposphere (MOPITT), provided by the Canadian Space Agency

In addition, NASA provided the spacecraft and launch vehicle, an Atlas II-*AS*[4].

While the instrument manifest is still largely operational, the short-wave infrared (SWIR) data from ASTER became unavailable after that subsystem's design life. The robust array of similar and extended-capability instrumentation currently in orbit on other Earth-observing platforms—both in the A-Train[5] and elsewhere—can make up for this small lack of data.

Terra's Data

A window into the scientific planning that formed the core of its implementation in *Terra* is provided by noting that together, the five instruments generate 79 data products, designed to provide their own information and to work in concert with other data products to further expand our knowledge of Earth's systems. The data are provided in *hierarchical data format* (HDF), a commonly used system across many disciplines and that has available many tools to search, browse, and display the resulting files.

Key to the success of EOS was the implementation of the EOS Data and Information System (EOSDIS[6]), with data repositories located at the Goddard Earth Sciences Data and Information Services Center and several discipline-specific Distributed Active Archive Centers (DAACs). Specifically, these include the Atmospheric Science Data Center (ASCD) Level 1 and Atmosphere Archive and Distribution System; the Land Processes DAAC; and the National Snow and Ice Data Center (NSIDC). Users with appropriate facilities may also access MODIS via *direct broadcast* capabilities. Additional information on Terra's data and acquisition and analytical capabilities is found at *terra.nasa.gov/data*.

Terra's Findings

For more than 15 years, the marvelous piece of technology called *Terra* has enabled new discoveries in Earth System Science. Dedicated engineers and scientists work together to calibrate instruments, process and store the vast quantities of data returned, validate results, and continue to coax cutting edge science out of aging hardware. The results are manifold and too many to describe here. However, in an effort to provide at least a sense of what Terra has provided us, in the rest of this article we will explore 15 findings—on an instrument-by-instrument basis, listed alphabetically—that are interesting and useful in their own right, and that serve as examples of what Terra (and its follow-on EOS and international-partner missions) have accomplished and will continue to accomplish for years to come. Short descriptions of each instrument's observational capabilities will precede example findings. The order of the examples is in no way indicative of prioritization of relative importance.

For more than 15 years, the marvelous piece of technology called Terra has enabled new discoveries in Earth System Science. Dedicated engineers and scientists work together to calibrate instruments, process and store the vast quantities of data returned, validate results, and continue to coax cutting edge science out of aging hardware.

[4] A complete description of the Terra mission, including its five instruments and data products, can be found in the *2006 Earth Science Reference Handbook* (*eospso.gsfc.nasa.gov/sites/default/files/publications/2006ReferenceHandbook.pdf*), pp. 225-237.

[5] For a description of the A-Train, refer to the January-February 2011 issue of *The Earth Observer* [**Volume 23**, **Issue 1**, pp. 12-23].

[6] For perspective on the development of EOSDIS, see "EOSDIS: Where We Were and Where We Are—Parts I and II" in the July–August 2009 [**Volume 21**, **Issue 4**, pp. 4-11] and September–October 2009 [**Volume 21**, **Issue 5**, pp. 8-14] issues of *The Earth Observer*.

ASTER

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a high-spatial-resolution instrument—the only such on Terra—at resolutions ranging from 15 m (~49 ft) to 90 m (~194 ft). It images Earth in 14 wavelengths across visible and infrared wavelengths, to take measurements of land surface temperature, emissivity, reflectance, and elevation.

1. ASTER Global Digital Elevation Model (GDEM):

In 2009 the ASTER GDEM was completed, revealing the topography of the land surface of Earth at the highest spatial resolution then available. Instead of loading up equipment and supplies and then trekking into the most remote parts of the world (e.g., Siberia) and then repeating this task over every 30-m (~98-ft) section of land on Earth, many such trips are no longer necessary with the completion of the ASTER GDEM. Indeed, data from ASTER were used to create the most detailed inventory of topography on Earth. The map in **Figure 1** shows the resulting topography for Earth's land surfaces.

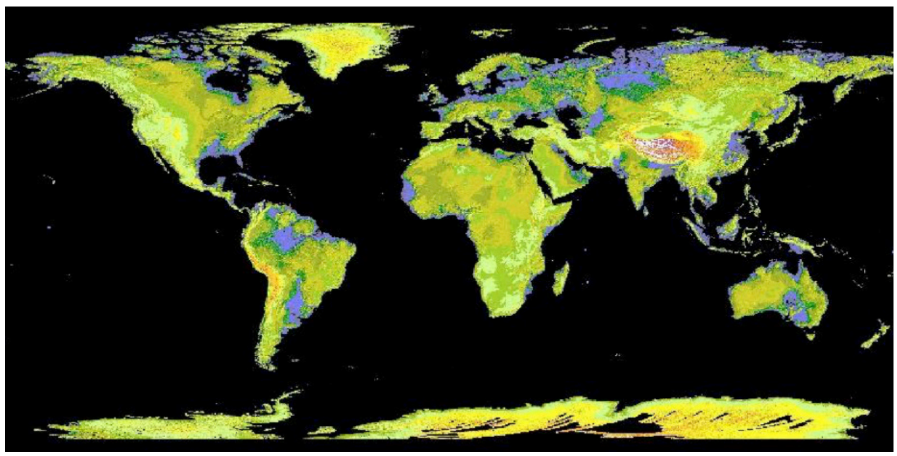

Figure 1. Blue and dark green areas are lower elevations than yellow areas. Red areas are higher elevations. These are highest over the Himalayas, the highest land elevations in the world. **Image credit:** NASA/Goddard Space Flight Center/METI/Japan Space Systems, and U.S./Japan ASTER Science Team

Such in-depth knowledge of Earth's topography is important in understanding climate impact studies that study how control factors such as evaporation, water flow, mass movement, and forest fires can impact climates and further change Earth's surface; the ASTER GDEM supports these studies. In addition, hydrologists use the information from the ASTER GDEM to understand the movement of water, glaciers, and ice over Earth's surface. Further, more accurate models of Earth's land surface leads to improvements in weather forecast models.

The ASTER GDEM is also used to help aircraft guidance systems locate potential risks in areas where there may be an unsupported airstrip, such as in military actions, or when assistance is being sent to areas affected by catastrophic events.

The ASTER GDEM is a collaboration between the Ministry of Economy, Trade, and Industry (METI) of Japan and NASA. The data are free to all users.

For more information about the ASTER GDEM, visit *asterweb.jpl.nasa.gov/gdem.asp*.

2. ASTER and Advanced Industrial Science and Technology (AIST) Global URban Area Map [AGURAM]:

AGURAM is the only high spatial resolution map of the extent of urban areas for the 3750 cities whose population is greater than 100,000.

While it's fun to look for notable landmarks in these images, these are more than just "pretty pictures;" there are a number of important applications. At a high resolution of 15 m (~49 ft) per pixel, these data give a unique view of human impact on the otherwise "natural" world, and help city planners and scientists better understand how these local impacts contribute to changes globally. For example, by looking at the image, it is easy to identify areas of permeable versus impermeable surfaces and to identify the effects these surfaces have on watersheds. AGURAM also allows scientists to study *urban heat islands* and their effects on biodiversity.

Not only are such data being used to track changes in and around cities, they are also used to compare city structure and to support planning for cities of similar size.

For an example of how ASTER/AIST AGURAM is being used, visit *cesa.asu.edu/urban-systems/100-cities-project*.

3. ASTER Global Emissivity Database (GED):

Emissivity is defined as how well Earth's surface emits radiation. Higher emissivity materials emit more radiation at a given temperature than low emissivity materials. Emissivity is directly related to the composition of Earth's surface; unlike surface temperature, it does not depend on weather conditions or the angle of the sun in relationship to Earth.

The ASTER GED is a global, 90-m (~295-ft) spatial resolution, emissivity map of Earth. Other orbiting instruments—e.g., the Moderate Resolution Imaging Spectroradiometer (MODIS), Tropospheric Emission Spectrometer (TES) onboard Aura, and Advanced Infrared Sounder (AIRS) onboard Aqua—used the ASTER GED to validate and improve their data products, e.g., atmospheric gas composition. Such information is also crucial for accurate retrieval of land surface temperature, a component of Earth's energy budget (see also CERES, following).

For more information about the ASTER GED, visit *emissivity.jpl.nasa.gov/aster-ged*.

CERES

There are two Clouds and the Earth's Radiant Energy System (CERES) instruments onboard Terra, designed to explore Earth's radiation budget and the roles that clouds play in modulating radiative fluxes from the surface to the top of the atmosphere by examining solar-reflected and Earth-emitted radiation. As of this writing, there are also operational CERES instruments on two other satellites: Aqua and Suomi National Polar-orbiting Partnership (NPP).

4. CERES measurements of Earth's albedo:

As is frequently the case in just about any kind of research, early results can change over time. In the early days of CERES data, Earth's *albedo*—the ratio of reflected radiation from the Earth to the incoming solar radiation—was thought to be in decline. Albedo is a function of the reflectivity of Earth's surface (land and ocean) and atmosphere, which makes it a key variable in understanding how Earth's energy balance is controlled. **Figure 2** shows by how much the amount of sunlight reflected into space changed between March 1, 2000 and December 31, 2011. This global picture of reflectivity (also called albedo) appears to be a muddle, with different areas reflecting more or less sunlight over the 12-year record. Based on these data, Earth's albedo didn't change much in 12 years—although there were substantial inter- and intrannual differences, particularly over specific regions, such as described in module #5, "Increased absorption of solar energy in the Arctic."

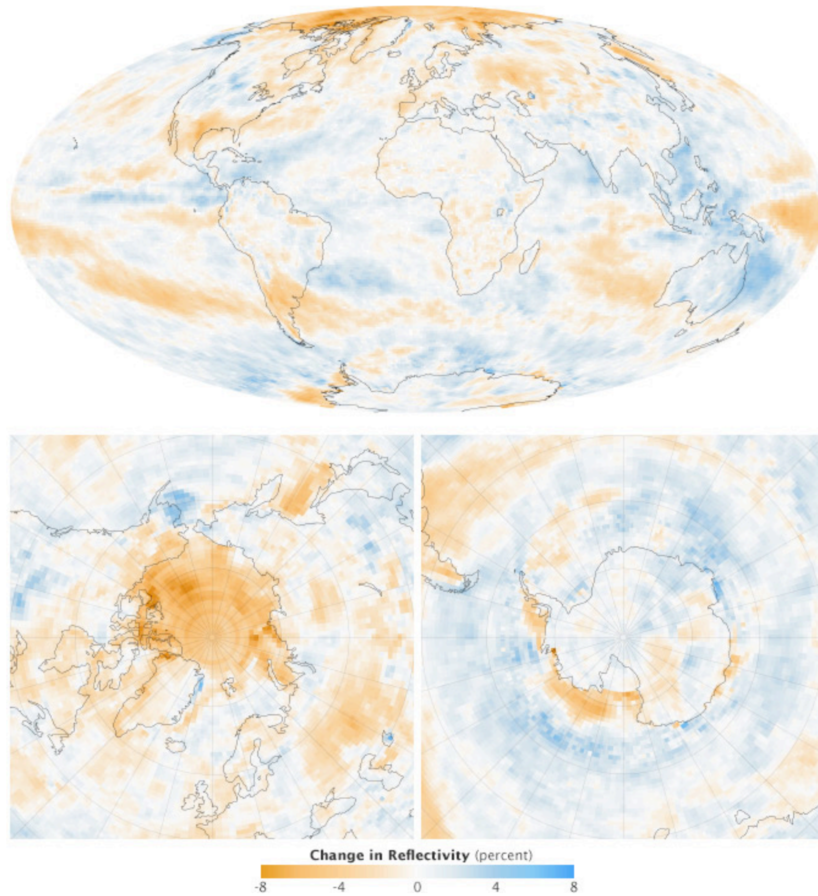

Figure 2. *Change in Earth's reflectivity as measured by CERES between March 1, 2000 and December 31, 2011 from three different viewpoints.* Shades of blue indicate areas that reflected more sunlight over time (indicating increasing albedo), while orange areas denote less reflection over time (decreasing albedo). **Image credit:** NASA's Earth Observatory and Robert Simmon

For more information, visit *terra.nasa.gov/news/measuring-earths-albedo*.

5. Increased absorption of solar energy in the Arctic:

Researchers using CERES data from Terra (and the Aqua and Suomi NPP platforms) have found a 5% increase in absorption of solar energy over the Arctic Ocean between 2000 and 2014. This increase is attributed to increased melting of surface ice in the region, with consequent decrease in albedo and increase in absorbance by the newly exposed darker ocean waters. The Arctic is presenting significant sensitivity to climate change, so data such as these are yet another "arrow" in the research quiver that may further allow greater insight into climate change phenomena.

For more on this finding and for a graphic representation of the data, see the News Story on **page 44** of this issue, and visit *www.nasa.gov/press/goddard/2014/december/nasa-satellites-measure-increase-of-sun-s-energy-absorbed-in-the-arctic/#.VJhm8kCbQg*.

MISR

Unlike many instruments that point in one direction—usually straight down (or *nadir*) or through the atmosphere at Earth's *limb*—Terra's Multi-angle Imaging SpectroRadiometer (MISR) points in nine different angles. Each camera takes measurements in four wavelengths across the visible and into the infrared. Its capabilities allow measurements of natural and human-caused particulate matter in the atmosphere, various cloud parameters, and the types and extent of land surface cover.

6. Eighty percent of the world's population breathes polluted air:

Data from MISR and MODIS have been combined to show that significant numbers of the world's population breathe polluted air. Before Terra, there was no method to use satellites to distinguish aerosols close to the ground from aerosols further up in the

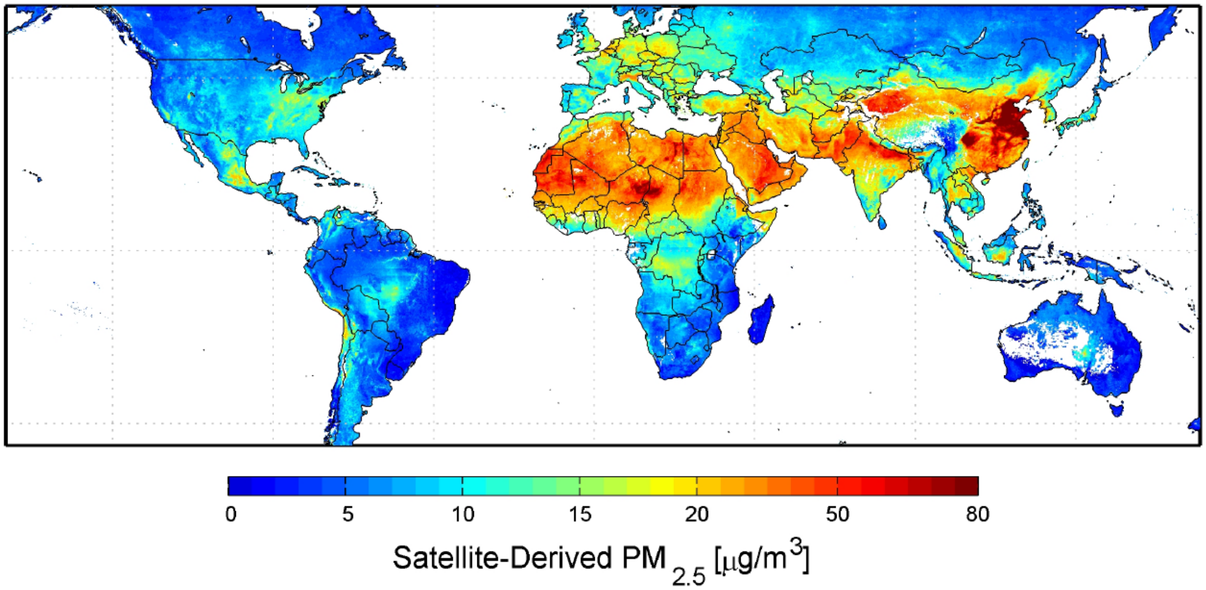

Figure 3. Global satellite-derived map of $PM_{2.5}$ averaged from 2001 through 2006. The map shows very high levels of $PM_{2.5}$ in a broad swath stretching from the Saharan Desert in Northern Africa to Eastern Asia. Levels of $PM_{2.5}$ are comparatively low in the U.S., although noticeable pockets are clearly visible over urban areas in the Midwest and East. Reds and oranges represent higher-levels of particules; blues and greens are lower concentrations. **Image credit:** Dalhousie University/Aaron van Donkelaar

atmosphere. MISR, with its multi-angle capabilities, is able to see the same column of air from multiple angles, thus making it possible to differentiate particles close to the ground from particles higher in the sky.

The map shown in **Figure 3** shows the global average levels of fine particulate matter ($PM_{2.5}$) between 2001 and 2006, the most comprehensive view of the health-sapping particles to date. While the data portrayed here are not the most accurate over developed countries, it is important to note that this is the first such satellite record over several developing countries. When compared with maps of population density, it suggests more than 80% of the world's population breathe polluted air that exceeds the World Health Organization's recommended level of 10 μg/m^3.

Using these datasets, epidemiologists can look more closely at how long-term exposure to particulate matter in rarely studied parts of the world affects human health. Some areas that are of particular interest include Asia's fast-growing cities or areas in North Africa with dust in the air.

For more information on the detrimental effects of air pollution on human health visit *www.nasa.gov/topics/earth/features/health-sapping.html*.

7. Wildfire plumes reach higher in the troposphere than once thought:

MISR smoke plume observations show that a significant fraction of wildfire plumes are injected into the *free troposphere*—i.e., the part above the temperature inversion layer. Such information is necessary to ascertain long-range dispersal of the particulates. Higher altitude plumes are associated with greater radiative fire heat flux, measured by MODIS. Data taken over North America have shown that between 10% and 30% of wildfire plumes reached the free troposphere as dust and smoke, with consequences for downstream air quality. Particles from these events can have longer lifetimes in the less-turbulent upper troposphere. Understanding such phenomena has significant value for modeling smoke environmental impacts and aerosol transport, with consequent effects on climate change.

For additional information, visit *climate.nasa.gov/news/41*.

8. Longer melt season from cloud cover over Arctic Ocean:

Another corroborative dataset made possible from Terra, combines data from MISR and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP[7]). Data retrieved over the Arctic Ocean and the Beaufort and East Siberian Seas during the month of October from 2000 to 2010 shows that cloud coverage at altitudes between 0.5 and 2 km (~0.3 and 1.2 mi) has been increasing. Because lower clouds have a net warming effect on the surface in late fall and winter, these findings imply a longer melt season and positive cloud temperature feedback, providing significant support for a feedback hypothesis that involves interactions between boundary layer clouds, water vapor, temperature, and sea ice in the region.

More detailed information on this topic is available at *onlinelibrary.wiley.com/doi/10.1029/2011JD017050/full*.

MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) has an extremely broad swath, at 2300 km (~1429 mi), but with a spatial resolution on the order of 250 m (~820 ft). With its 36 spectral bands and the ability to take measurements globally every couple of days, it is something of the "Swiss Army Knife" of sensors. Clouds, their properties, and locations are a clear target, as are aerosols, water vapor, and temperature. MODIS also addresses the global carbon cycle, with focus on the changes in land cover, either natural (e.g., due to fires) or anthropogenic (e.g., due to agriculture or city structure). A MODIS instrument also flies onboard Aqua.

9. Detailed views of hurricanes and related storms:

Among its many other capabilities, Terra tracks storms in the middle of the ocean before they enter the view of geostationary weather satellites. This makes it possible to monitor the hurricanes long before they make landfall. Before Terra, satellites like those in the Nimbus series (first launched in 1964) monitored hurricanes over the oceans, but resolution of what was then known as the "High-resolution Infrared Radiometer" was poor by today's standards, at only 10 mi (~16 km) per pixel at nadir. In contrast, when MODIS began collecting images in 2000, the resolution was far more detailed at 0.15 mi (~0.25 km) per pixel. This advance in technology allows researchers to study hurricanes in much greater detail and use the information to develop and implement better weather models, thereby helping people better prepare in advance for major hurricanes. For more comparisons between legacy and modern storm-tracking capabilities, visit *earthobservatory.nasa.gov/NaturalHazards/view.php?id=84542&src=nha*.

10. Tracking carbon from its source to its sink:

The chemistry of life is frequently referred to as "organic chemistry," which is more formally the chemistry of carbon, and is often measured in ecosystems as the net carbon uptake (incorporation into biomass) by vegetation. For the first time, change in this uptake, or *net primary production* (NPP) for Earth, globally, was calculated using MODIS data, making it possible to visualize and quantify how NPP changed due to rising global temperatures. Previous studies indicated that as temperatures increased, NPP also increased. This was found to be valid for the Northern Hemisphere, but unlike what was originally expected, global net productivity has actually decreased during the time Terra has been collecting data due to reductions in the Southern Hemisphere and the tropics, due to increased drought and dryness. NPP also is used to study the effects of El Niño events, climate change, droughts, pollution, land degradation, and agricultural expansion.

For more information on MODIS contributions to NPP, visit *earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD17A2_M_PSN*.

[7] CALIOP flies onboard NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) spacecraft.

11. Tracking seasonal and spatial distribution of fires worldwide with near-real-time data:

Fires occur year-round, but most fires occur in July, August, and September in both the Northern and Southern Hemispheres. MODIS on Terra has tracked fires globally for the last 15 years and will continue to monitor fires globally (along with MODIS on the later-launched Aqua platform). In addition to useful visible images (see **Figure 4**), the global distribution of *fire radiative power* (FRP)—the amount of thermal radiation (heat) emitted by a fire—could be identified via remotely sensed data. Low FRP is associated with cropland burning, such as slash and burn methods of farming, whereas high FRP is associated with grasslands in the tropics. However, in boreal regions high FRPs occur in areas with more tree cover.

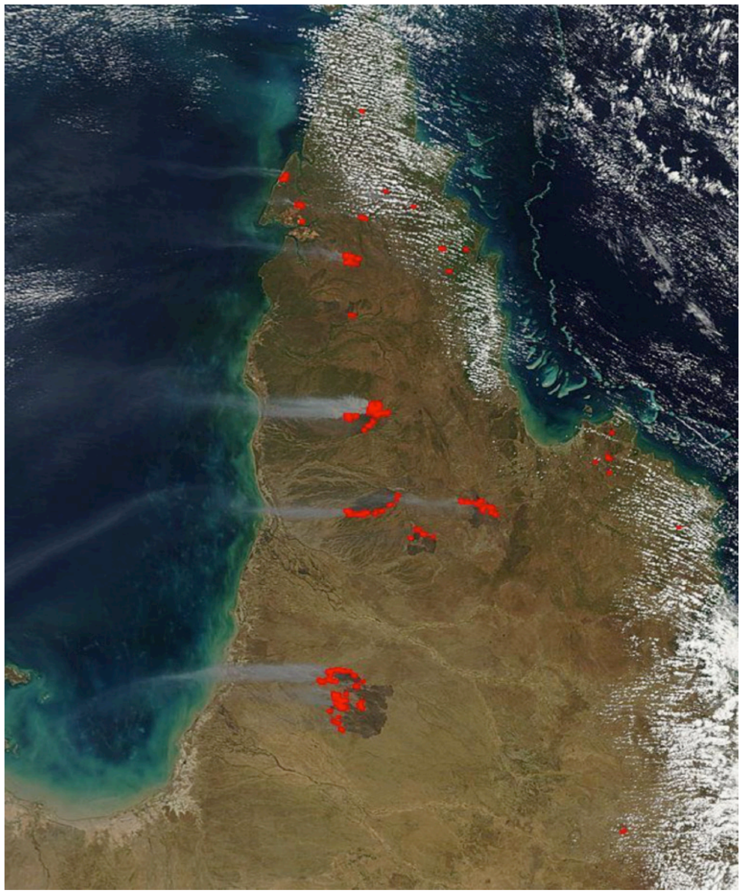

Figure 4. MODIS true-color image of fires across Cape York Peninsula on October 19, 2014; active fires are identifiable in this image by the red outlines at the leading edges of the smoke plumes from the fires, which are seen pointing west; north is up. **Image credit:** NASA/LANCE Rapid Response Team

An excellent discussion of these observations is found in the *Journal of Geophysical Research* paper that is available at *ftp://windhoek.nascom.nasa.gov/private/ichoku/PAPERS/Giglio_2006_JGR_modfire.pdf*.

MOPITT

The name—Measurements of Pollution in the Troposphere (MOPITT)—pretty much describes what MOPITT is designed to do. Specifically, it looks into the lower atmosphere—the troposphere—to explore interactions between that region and Earth's biosphere. Its main focus is on carbon monoxide and its distribution in the atmosphere.

12. First observations of volcanic carbon monoxide from space:

The composition and magnitude of volcanic gas emissions contain keys to understanding and predicting volcanic events. In addition some volcanic gases—e.g., sulfur dioxide (SO_2)—can impact climate by forming aerosols, which reflect solar radiation. Traditionally, volcanic gases are mostly measured from the ground or using airborne instruments, but MOPITT allows scientists to study carbon monoxide (CO) emissions from volcanoes from space, reducing sampling limitations and associated costs**.**

The identification of volcanic CO was achieved using data from MOPITT and the Infrared Atmospheric Sounding Interferometer (IASI[8]). Supporting data came from the Ozone Monitoring Instrument (OMI; onboard Aura), which measures SO_2 and aerosols and MODIS, which measures aerosols only. The four instruments together provide a complete picture of the impact of volcanoes on air quality and climate. Using this information, it is now known that CO from volcanic emissions is not negligible. Globally, on average CO emissions from volcanic sources are comparable to the amount of CO produced from fuels and biofuels in Australia.

For additional information on this topic, visit *www2.acd.ucar.edu/news/first-satellite-identification-volcanic-carbon-monoxide*.

13. MOPITT captures carbon monoxide emissions in Beijing before and during the 2008 Summer Olympics:

MOPITT allowed scientists to quantify and visualize the amount of CO emissions in Beijing, China before and after the 2008 Summer Olympics. Starting in August 2008—several months before the games—Beijing instituted traffic restrictions that had a profound impact on CO and carbon dioxide emissions. However, pollution levels increased to seasonal norms after the festivities ended.

For further information, visit *www.nasa.gov/topics/earth/features/earth20120724.html*.

14. Tropospheric carbon monoxide is decreasing:

In the last fifteen years, since MOPITT began collecting data, a trend in CO levels has emerged. Global levels of CO in the lower atmosphere declined since 2000 at a rate of about 1% per year; the reasons for the decrease are under examination. MOPITT data were combined with data from other instruments that are able to measure CO in the atmosphere: Observations from MOPITT, AIRS, TES, and IASI were all used. The study found that CO levels decreased in both the Northern and Southern Hemispheres, but there was a greater reduction in the Northern Hemisphere than the Southern Hemisphere. The mechanisms for these observations are still under study. For additional information, visit *www.nar.ucar.edu/2012/lar/nesl/iiih1-moppitt-highlight-regional-trends-co-decade-satellite-observations.html*.

15. Tropospheric carbon monoxide levels from biomass burning are greater than originally thought:

Before Terra, there were no long-term measurements of CO in the lower atmosphere that could show the globally transported pollution coming from *biomass burning*—the burning of vegetation from both human-caused and natural fires.

CO is the second most prevalent gas emitted from biomass burning, an example of which is found in **Figure 5**. It is second only to carbon dioxide. Tracking and monitoring CO is important to understanding air quality and is used to advise people when air quality is hazardous.

[8] IASI flies onboard European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)'s METOP satellites METOP-A and –B; a –C flight is due for launch in 2018. The METOP satellites are are among those described in "An Overview of Europe's Expanding Earth-Observation Capabilities" in the July-August 2013 issue of *The Earth Observer* [**Volume 25, Issue 4**, pp. 4-15].

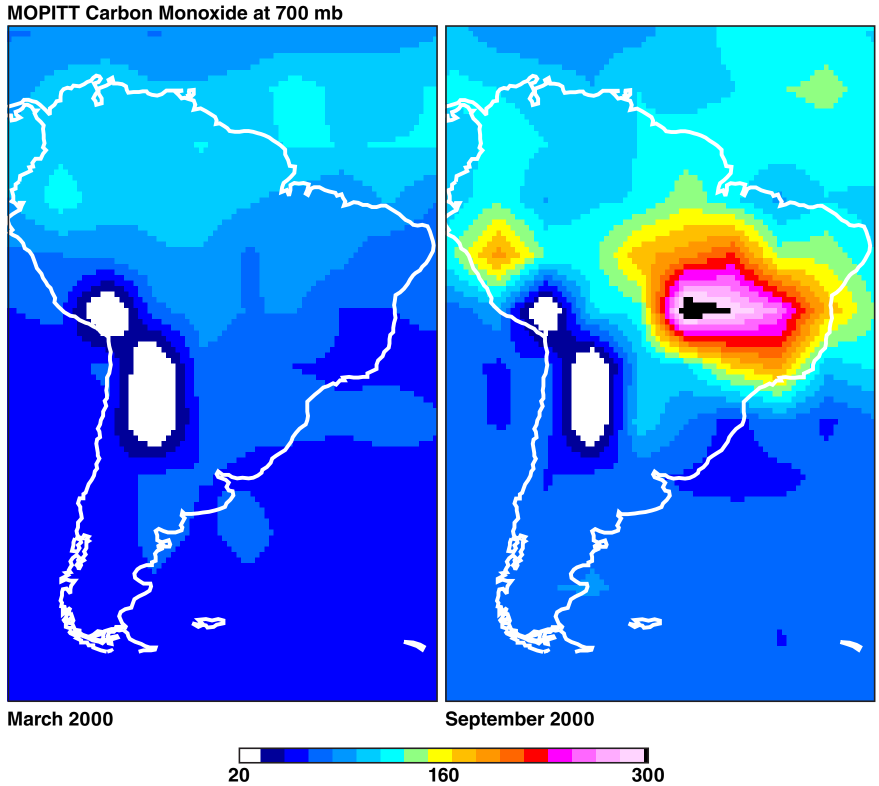

Figure 5. Mid-tropospheric CO levels at 12,000 ft (~4 km) altitude over South America. The high levels in September [*right*] over Brazil arise from biomass burning. Other relatively high levels as compared with March come from biomass burning in South Africa, transported by easterly winds over the Atlantic Ocean. **Image credit:** David Edwards, John Gille, MOPITT Science Team, NCAR

For more information on this finding, visit *www.nar.ucar.edu/2012/lar/nesl/iiih1-moppitt-highlight-regional-trends-co-decade-satellite-observations.html*.

Summary

The utility of the carefully designed complementarity of Terra's instruments is clearly evident in the data and research results represented here. The spacecraft continues to provide key data to address the interrelationships between Earth's various systems, long after its planned lifetime. With only one minor glitch, those data continue to be obtained and disseminated to a wide range of communities, giving further testimony to the excellence of those far-sighted individuals and organizations responsible for Terra and its increasingly large family of low-Earth-orbit remote-sensing instruments. Terra was the first such comprehensive platform; its success bodes well for continued examination of our home planet. ■

The authors would like to thank **Kurt Thome** [GSFC—*Terra Project Scientist*] for his careful review of this article and eminently helpful suggestions.

We also thank **Mike Abrams** (ASTER), **Lin Chambers** (CERES), **Dave Diner** (MISR), **Michael King** (MODIS), and **Helen Worden** (MOPITT), for their contributions to content and for their continued support of Terra data and science.

SMAP: Mapping Soil Moisture and Freeze/Thaw State from Space

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The SMAP mission is NASA's first Earth-observing satellite mission designed to collect continuous global observations of surface soil moisture and freeze/thaw state every 2 to 3 days at spatial resolutions of 3 to 40 km (~2 to 25 mi).

Introduction

On January 31, 2015, NASA successfully launched the Soil Moisture Active Passive (SMAP) spacecraft from Vandenberg Air Force Base near Lompoc, CA, aboard a United Launch Alliance Delta II *7320-10C*.

The SMAP mission is NASA's first Earth-observing satellite mission designed to collect continuous global observations of surface soil moisture and freeze/thaw state every 2 to 3 days at spatial resolutions between 3 and 40 km (~2 to 25 mi). As suggested by the name "Active Passive," SMAP will carry an *active* microwave radar and a *passive* microwave radiometer that will measure across a swath 1000-km (~621-mi) wide—see **Figure 1**.

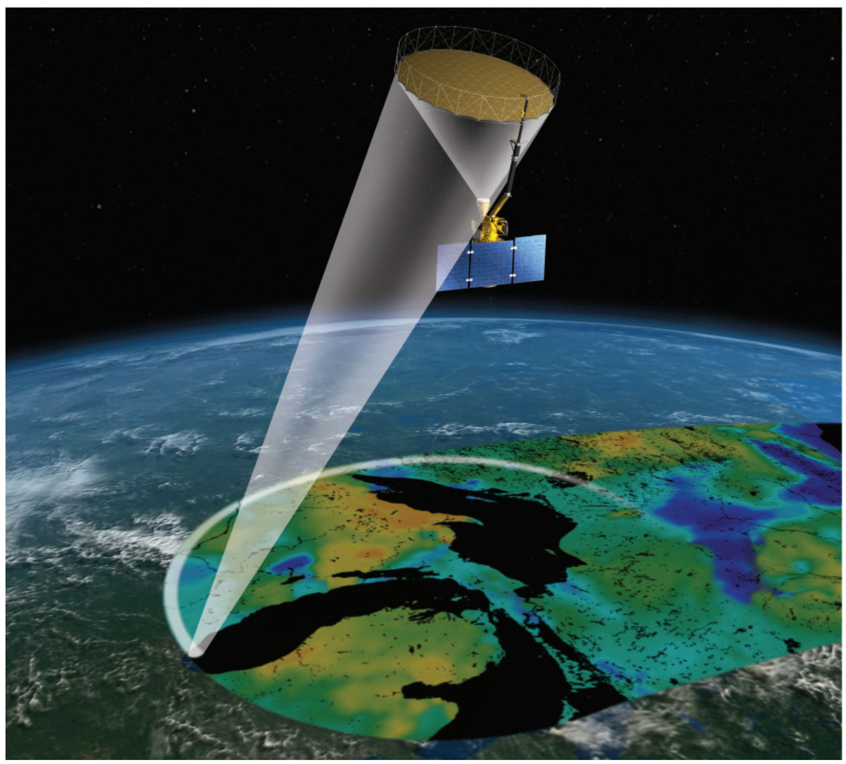


Figure 1. Artist's rendition of the SMAP observatory collecting data from space. **Image credit:** NASA

We begin this article with some background on soil moisture and its place in the Earth System. Then we provide details about the mission; in particular, the instrumentation, spacecraft design, planned data acquisition, and a discussion about how data from SMAP will be used for the betterment of society. For additional information about the mission, visit *smap.jpl.nasa.gov*.

Soil Moisture in the Earth System

Soil. It is one of our planet's most useful natural resources, as it is made up of minerals, gases, liquids, organic matter from biological waste and from decomposing life forms, and living organisms, all of which affect plant life and—ultimately—much of life on Earth. Important processes occur in soil that help sustain life on Earth such as the absorption, infiltration, storage, and release of water—the so-called "universal solvent" that is key to terrestrial biology. In addition, soil provides a haven for organic nutrients; a place for plants to grow; habitats for animals; and a medium for gas exchange (e.g., carbon dioxide, methane, and water vapor) between the land and atmosphere.

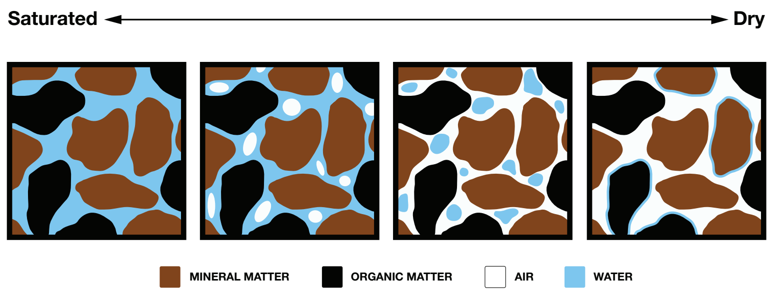


Figure 2. Soil is made up of four main components: mineral matter, organic (carbon-based) material, air, and water. This graphic depicts relative soil moisture conditions from saturated to dry. Note that even in the driest of soils there remains a very small amount of water in the pores—so tightly bound to individual soil particles that it is unavailable to plants. **Image credit:** NASA

Water is one of the most important components of soil, but the volume of water contained within a given volume of soil—or *soil moisture*—can fluctuate annually, seasonally, daily, and even hourly, due to changes in water availability from precipitation, irrigation, and evaporation from the soil and plants—see **Figure 2**. To better understand changes in the amount of water stored and released between the land and atmosphere, scientists study soil moisture conditions as well as whether the water contained within the soil is frozen or thawed—called its *freeze/thaw state*.

Soil moisture and its freeze/thaw state are key components in understanding Earth's water, energy, and carbon cycles; they also impact weather and climate. Large amounts of energy are required to evaporate water from Earth's surfaces; therefore, soil moisture has significant impacts on surface energy fluxes and influences the global energy cycle. Similarly, soil moisture and its freeze/thaw state are key determinants of the global carbon cycle. For example, carbon uptake by forests in boreal regions in the Northern Hemisphere is influenced by the length of the *growing season*—the time between the spring thaw and winter freeze transitions. Variations in soil moisture also affect the evolution of weather and climate phenomena, particularly over continental regions, and contribute immensely to a region's flood or drought potential, which impacts agricultural productivity, as well as human populations and constructs.

Soil moisture and its freeze/thaw state are key components in understanding Earth's water, energy, and carbon cycles; they also impact weather and climate.

While ground-based instruments can be used to obtain reliable measurements of soil moisture at specific locations, there are large spatial gaps between instrument sites; therefore, they cannot be used to make measurements across large areas. Satellite observations from space, however, can cover broad areas and provide frequent measurements in enough detail to allow scientists to determine the amount of water contained within soil, as well as to distinguish between frozen and nonfrozen soil.

SMAP Mission

The SMAP mission is one of four *Tier-One* missions recommended by the National Research Council's Decadal Survey[1] in 2007. After launch, the spacecraft was placed in a near-polar, sun-synchronous orbit 685 km (~425 mi) above Earth, crossing the equator at 6:00 AM (descending node) and 6:00 PM (ascending node)—see **Table 1**.

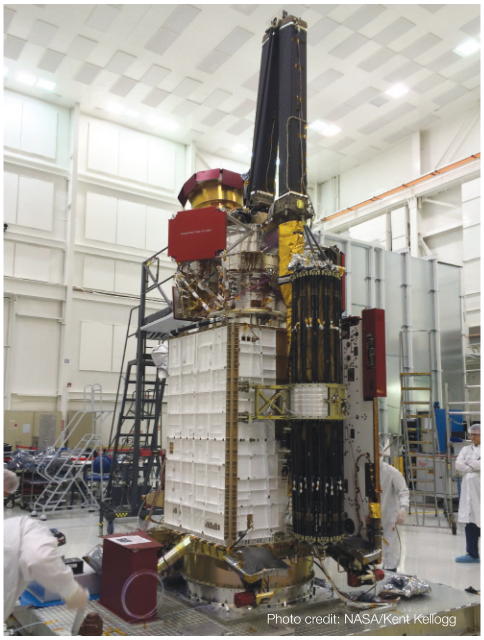
Table 1. SMAP orbital characteristics.

Orbit	Altitude	Equatorial Crossing Time	Inclination	Orbit Duration	Repeat Cycle	Revisit
Near-polar, sun-synchronous	685 km (~425 mi)	18:00 hrs [6:00 AM (descending node) and 6:00 PM (ascending node)]	98.12°	98.5 minutes	8 days (exact orbit repeat)	2-3 days

SMAP's space-based ability to measure global soil moisture and freeze/thaw state with unprecedented accuracy and spatial resolution allows scientists to better understand

[1] The 2007 National Research Council (NRC) Decadal Survey report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, provides the basis for the future direction of NASA's space-based Earth observation system.

the processes that link the Earth's water, energy, and carbon cycles, as well as to enhance the predictive skills of weather and climate models. In addition, scientists can use these data to develop improved flood prediction and drought monitoring capabilities. Additional benefits include improved water-resource management, agricultural productivity, flood potential, and wildfire and landslide predictions.



All spacecraft components, the instruments, feedhorn, and reflector boom assembly were integrated on the observatory inside the cleanroom at NASA/Jet Propulsion Laboratory (JPL). **Image credit:** NASA

Data from SMAP also allow more accurate projections of seasonal and interannual variations of soil moisture and freeze/thaw state. These data help quantify the nature, extent, timing, and duration of landscape seasonal freeze/thaw state transitions that are key to determining the length of the growing season and the resulting impact of growing season changes on global water, energy, and carbon cycles, as well as other aspects of society. The ability to detect variations in the timing of spring thaw and the subsequent length of the growing season also allows scientists to determine how much carbon plants absorb from the atmosphere each year, to estimate terrestrial carbon sources and sinks, and to quantify net carbon flux. In addition, SMAP freeze/thaw state measurements contribute to understanding how ecosystems respond to and affect global environmental change (i.e., climate change), thereby improving regional mapping and prediction of ecosystem processes, particularly in boreal regions.

The Instruments Onboard

The SMAP instruments consist of a passive L-band radiometer and an active L-band radar, both with multiple polarizations. The L-band frequency enables observations of soil moisture through clouds and moderate vegetation cover both during the day and at night. Multiple polarizations allow for accurate soil moisture estimates to be made with corrections for vegetation, surface roughness, *Faraday rotation* (i.e., interactions between electromagnetic radiation and Earth's magnetic field), and other perturbing factors. Both instruments have also been designed to mitigate radio frequency interference, which comes from ground-based radars and microwave transmissions that can contaminate the L-band measurements.

The 1.41-GHz radiometer measures the intensity of microwave radiation emitted from the Earth's surface (i.e., *brightness temperature*) to provide estimates of soil moisture at a spatial resolution of approximately 40 km (~25 mi). Specifically, the radiometer acquires measurements in four channels [vertical (V) and horizontal (H) polarization, and third and fourth Stokes parameters—parameters which represent the polarization state of electromagnetic radiation] with an antenna temperature precision of better than 0.5 K.

In the cleanroom, **NASA Administrator Charles Bolden** [*left*] learns about the SMAP radar instrument assembly from a flight system engineer [*right*]. **Image credit:** NASA

The 1.26-GHz radar transmits microwave radiation in two linear polarizations and measures the scene backscatter in multiple polarimetric channels to provide estimates of both soil moisture and freeze/thaw state. Specifically, the radar employs *synthetic-aperture* as well as *real-aperture* radar processing, which results in high-resolution between 1 and 3 km and low-resolution (30-km) radar data, respectively.

Observations from the radiometer yield high soil moisture accuracy with coarse spatial resolution, while observations from the radar yield high spatial resolution with lower soil moisture accuracy. By combining observations from the radiometer and radar, scientists are able to provide estimates of soil moisture in the top 5 cm (~2 in) of soil at 9-km (~6-mi) spatial resolution in three-day intervals—excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and dense vegetation such as tropical forests (i.e., areas with vegetation water content greater than approximately 5 kg/m^2). Soil freeze/thaw state is determined using data from the radar only at 3-km (~2-mi) spatial resolution in two-day intervals. The high-resolution radar data are critical to accurately determine freeze/thaw state in the heterogeneous landscapes of the boreal region— i.e., north of 45° N latitude.

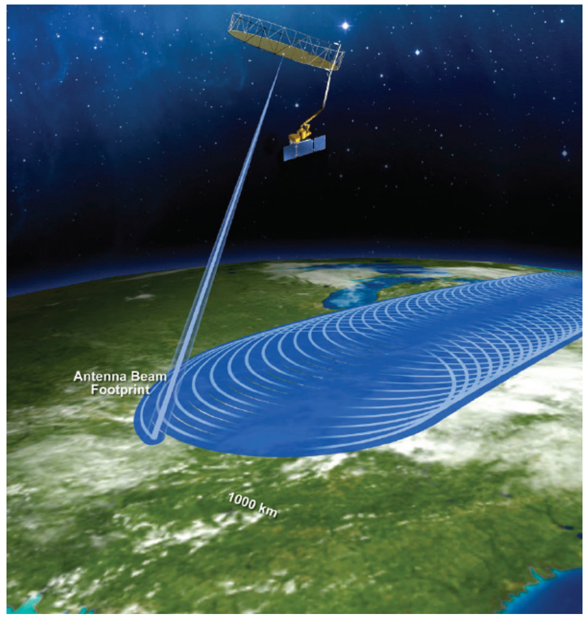


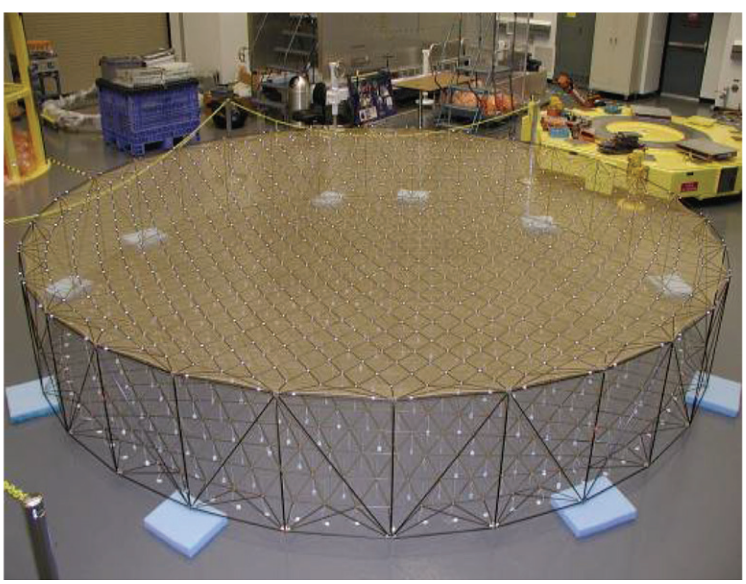
Figure 3. Schematic of the SMAP conically-scanning antenna beam mapping out a swath width of 1000 km (~621 mi) at the Earth's surface. Light blue depicts the antenna boresight direction, while dark blue depicts the real aperture footprint area (characteristic of the radiometer's spatial resolution). **Image credit:** NASA

How the Instruments Work

What makes the SMAP observatory unique is the lightweight, deployable mesh reflector antenna, or *reflector boom assembly*, measuring 6 m (~20 ft) in diameter. Both the radiometer and radar share the same feedhorn to transmit to and receive signals from the mesh reflector. The reflector assembly points towards the ground at a constant incidence angle of 40° and spins at ~14 RPM, resulting in conically scanned data—see **Figure 3**. This arrangement allows both instruments to collect data jointly across a 1000-km (~621-mi) wide swath, enabling global coverage every 2 to 3 days.

The reflector's 6-m diameter yields a radiometer footprint spatial resolution at the surface of 39 x 47 km (~24 x 29 mi), and a real-aperture radar (i.e., low-resolution radar) footprint resolution of 29 x 35 km (~18 x 22 mi) over the entire swath width (i.e., 1000 km, ~621 mi). Due to the reflector's unique scanning geometry, however,

By combining observations from the radiometer and radar, scientists are able to provide estimates of soil moisture in the top 5 cm (~2 in) of soil at 9-km (~6-mi) spatial resolution in three-day intervals—excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and dense vegetation such as tropical forests (i.e., areas with vegetation water content greater than approximately 5 kg/m^2).



Pictured here is the deployable mesh reflector antenna. **Image credit:** NGAS

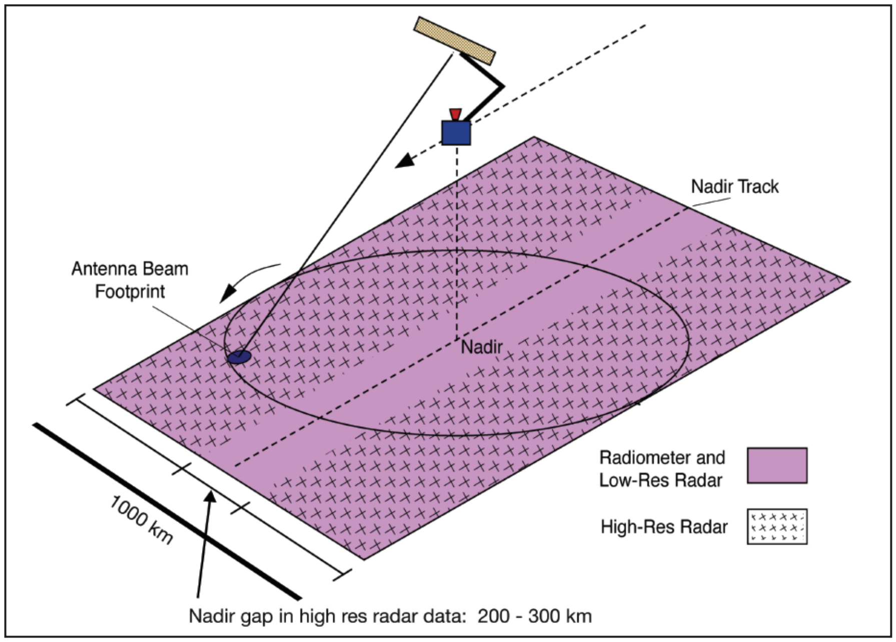


Figure 4. The amount of swath area covered by the radiometer and high- and low-resolution radars is shown here. The synthetic-aperture radar provides high-resolution data over the outer 700 km (~435 mi) of a given swath. **Image credit:** NASA

the synthetic-aperture (i.e., high-resolution) radar processing provides 1-to-3-km (~0.6-to-2-mi) data over the outer 70% of the swath only, i.e., not over the inner 300 km (~186 mi) of the swath—see **Figure 4**.

Spacecraft Design and Ground System

The SMAP spacecraft was built at NASA/Jet Propulsion Laboratory, leveraging avionics, software, and power electronics derived from previous planetary missions. The spacecraft was designed to accommodate the unique needs of a large spinning instrument in a compact package that could fit within a small launch vehicle fairing. The spacecraft structure is made of aluminum and includes large reaction wheels that provide momentum compensation for the large, spinning 6-m (~20-ft) diameter mesh reflector. The spacecraft supplies power, orbit and attitude control, communications, and data storage for the radiometer and radar. A solar array with three fixed panels provides power to the observatory components.

Built with a design life of three years, SMAP carries sufficient fuel for more than five years of normal operation.

Solid-state memory with large data storage capacity is aboard the spacecraft, and an X-band antenna transmits radiometer and radar data in real time or played back from the onboard memory upon command. The spacecraft's S-band transponder accommodates ground-based Doppler tracking for orbit determination rather than using the *global positioning system* (GPS), because the large spinning instrument antenna blocks GPS satellite visibility. Built with a design life of three years, SMAP carries sufficient fuel for more than five years of normal operation.

The SMAP mission ground system includes all the assets needed to command and operate the SMAP spacecraft in orbit, as well as to manage and distribute data. The SMAP Science Data System (SDS) converts telemetry downlinked from the SMAP observatory into science data products that are then provided to the science community for research and applications. Designed to process data products in a timely manner[2], the SDS facility includes computer hardware dedicated to operational data production as well as hardware for use by the SMAP science algorithm development team to enhance algorithm accuracy and performance.

The SDS is housed primarily at JPL, but with components at NASA's Goddard Space Flight Center (GSFC). Specifically, JPL is responsible for implementation of software to generate Level 1 instrument data products (both radar and radiometer) as well as

[2] All Level 0b and Level 1 products will be available within two hours (average mean latency over the mission) of availability of the Level 0a data at SDS for those products for which the complete orbit data have been received.

Level 2 and Level 3 geophysical data products. GSFC is responsible for the Level 1 radiometer algorithms and for implementing software to generate the value-added Level 4 geophysical data products produced by the GSFC Global Modeling and Assimilation Office (GMAO).

The SMAP baseline science data products will be generated within the project's SDS and made available publicly through two NASA Distributed Active Archive Centers (DAACs), the Alaska Satellite Facility (ASF) (for Level 1 radar products) and the National Snow and Ice Data Center (NSIDC) (for all other products).

The SMAP Team will coordinate the release of data product versions with the data centers and will ensure the completeness and accuracy of quality control information and validation status of the data products[3].

Serving Society and Making a Difference

SMAP data have high value for both science research and applications. The accuracy, resolution, and global coverage of SMAP soil moisture and freeze/thaw measurements are expected to be invaluable across many individual and interrelated science and applications disciplines including hydrology; climate; carbon, water, and energy cycles; and the meteorological, environmental, and ecological applications communities. Here, we detail the applications of SMAP data related to weather and climate forecasting, agriculture and rangeland productivity, drought, floods and landslides, and human health.

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Weather and Climate Forecasting

Soil moisture variations affect the evolution of weather and climate. Initialization of numerical weather prediction and seasonal climate models with accurate soil moisture information enhances their prediction skills and extends lead times useful for potential action: Improved seasonal climate predictions will benefit climate sensitive socioeconomic activities, including water management, agriculture, fire, and flood and drought hazards prediction and monitoring.

Agriculture and Rangeland Productivity

The availability of direct observations of soil moisture from SMAP will provide information on water availability to estimate productivity and potential crop yields, and provide realistic soil moisture observations as inputs for agricultural prediction models.

Drought

Soil moisture strongly affects plant growth and determines the fate of agricultural and rangeland productivity, especially during conditions of water shortage and drought. At present, there is no global *in situ* network for soil moisture monitoring; global estimates of soil moisture and plant water stress must be derived from models. These model predictions and drought monitoring can be greatly enhanced through assimilation of space-based soil moisture observations.

Floods and Landslides

Soil moisture is a key variable in water-related natural hazards such as floods and landslides. High-resolution observations of soil moisture will lead to improved flood forecasts, especially for intermediate-to-large watersheds—where most flood damage occurs. The surface soil moisture state is key to partitioning precipitation into infiltration and runoff amounts. Further, soil moisture in mountainous areas is one of the most important determinants of landslides. Hydrologic forecast systems initialized with mapped high-resolution soil moisture fields will therefore open up new capabilities in operational flood forecasting.

[3] *The Earth Observer* will report on data release dates in subsequent issues.

continued on page 33

NASA's Hyperwall: Around the World in 2014

Heather Hanson, NASA's Goddard Space Flight Center, Global Science and Technology, Inc., heather.h.hanson@nasa.gov

With more than 25 years of experience communicating NASA science to the world, the Science Program Support Office has been instrumental in NASA's outreach efforts, particularly in their ability to deliver NASA's science results, achievements, and ambitions face-to-face across the world.

Introduction

The Earth Observing System Project Science Office (EOSPSO)—now the NASA Science Program Support Office (SPSO)—dates back to 1988, the year NASA's EOS was first implemented. With more than 25 years of experience communicating NASA science to the world, the SPSO has been instrumental in NASA's outreach efforts, particularly in their ability to deliver NASA's science results, achievements, and ambitions face-to-face across the world.

Each year, the SPSO consults with NASA leadership to choose the most relevant and beneficial scientific conferences and public events for the office to support. These conferences and events include domestic (e.g., AGU, AMS[1]), international (e.g., IGARSS[2]), mission-related (e.g., mission launches), public (e.g., Earth Day), and political events where the office represents the U.S. (e.g., GEO, COP[3]). The goal is to exhibit NASA (in particular, the Science Mission Directorate and Earth Science Division) as a world leader in exploration, scientific research, and technology.

The most recent—and perhaps the most successful—communication platform used in such representation is the *Hyperwall*—see *About the Hyperwall*. For conferences and events where the Hyperwall is the centerpiece of the exhibit, the SPSO will contact NASA attendees (e.g., scientists) to enlist their aid in coordinating and developing a Hyperwall presentation. The popularity of this approach is clear, as it is common to have an audience of more than 100 people gathered around the Hyperwall during these presentations.

About the Hyperwall

The Hyperwall is a high-resolution (up to 5760 x 3240 pixels) video wall capable of displaying multiple scientific data visualizations and images, mostly from satellite measurements, simultaneously across an arrangement of screens. For exhibit purposes, the most commonly used arrangement is 9 screens in a 3 x 3 grid, with a tenth screen for descriptive text and supplemental information.

Many existing Hyperwall stories reveal change across space and time (e.g., landscape changes, water storage depletion), while others display large-scale still-images accompanied by descriptive, storytelling captions. The library of available content continues to grow, as the SPSO is always working with internal and external partners to incorporate new images and stories into the Hyperwall library. In 2013 a website to host *PowerPoint* and *Keynote* versions of Hyperwall content and stories was launched (*svs.gsfc.nasa.gov/hw*). The website allows public access to all existing Hyperwall stories—a great resource for those interested in using powerful visualizations and images to communicate NASA science.

Recent Conferences and Events Around the World

In 2014 NASA's Hyperwall traveled to 21 conferences and/or events[4]. To view photos from several of the events, visit *www.flickr.com/photos/eospso/sets*. Most recently, NASA's Hyperwall and support staff traveled to Sydney, Australia; Lima, Peru; and San Francisco, CA, in a 37-day span to close out 2014. Presented below are some excerpts from the travel log of that whirlwind world tour.

World Parks Congress

The first stop was the International Union for Conservation of Nature (IUCN) World Parks Congress in Sydney, Australia, November 12-19, 2014—which is held once a decade. Throughout the conference there were a number of Hyperwall talks presented by NASA scientists and partners that highlighted the use of NASA remote sensing data for protected area management—see **Table 1**. The talks were well attended and captivated a variety of onlookers—see **Photos 1-4**.

[1] AGU and AMS stand for American Geophysical Union and American Meteorological Society, respectively.
[2] IGARSS stands for International Geoscience and Remote Sensing Symposium.
[3] GEO and COP stand for Group on Earth Observations and Conference of Parties, respectively.
[4] Note that not all of these were Earth science events. The SPSO supports all of NASA's Science Mission Directorates—including Earth Science, Planetary Science, Heliophysics, and Astrophysics.

Table 1. Hyperwall talks at the World Parks Congress meeting.

Presenter	**Presentation**
Thursday, November 13	
Lawrence Friedl [NASA Headquarters (HQ)]	Earth Science Applications: Expanding Benefits to Society
Friday, November 14	
Matt Hansen [University of Maryland, College Park]	Forest Disturbance Mapping with Landsat: The Potential for Assessing Tropical Forest Protected Areas
Saturday, November 15	
Michael Abrams [NASA/Jet Propulsion Laboratory (JPL)]	Using Satellite Images for Conservation: Painless Access Using TerraLook
John Gross [U.S. National Park Service]	Climate Change in Yellowstone National Park
Hedley Grantham [Conservation International]	Near-Real-Time Satellite Monitoring for Improved Forest Management in the Tropics
Sunday, November 16	
Lawrence Friedl	Earth Science Applications: Expanding Benefits to Society
Woody Turner [NASA HQ]	Understanding Our Planet: The View from Space
Allison Leidner [NASA HQ]	Conserving Earth's Biodiversity: The NASA Perspective
Monday, November 17	
John Gross	Climate Change in Yellowstone National Park
Woody Turner	SERVIR: Using Earth Observations for Societal Benefit
Tuesday, November 18	
Hedley Grantham	Near-Real-Time Satellite Monitoring for Improved Forest Management in the Tropics
Michael Abrams	Using Satellite Images for Conservation: Painless Access Using TerraLook

Photo 1. John Gross [U.S. National Park Service] showed projected changes in several suitable habitats across the Beartooth Mountain Range (northeast of Yellowstone National Park in Montana) for whitebark pine between 2010 and 2099 using the NASA Earth Exchange Downscaled Climate Projections (NEX-DCP30) model. The results revealed how the suitable bioclimate habitat area for the important species is expected to shrink by 2099. **Photo credit:** NASA

Photo 2. Sylvia Earle [National Geographic *Explorer-in-Residence* and *Former Chief Scientist* of the National Oceanic and Atmospheric Administration (NOAA)] showed great interest in a Hyperwall visualization that showed sea surface currents, with temperatures represented by different colors, produced by the Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) model. **Photo credit:** NASA

Photo 3. Allison Leidner [NASA Headquarters] (not pictured) gave a tour of Earth science visualizations on the Hyperwall to a group of 30 students from Sydney Girls High School, an academically selective girls-only high school. **Photo credit:** NASA

Photo 4. Maggie Barry [New Zealand's *Minister of Conservation*] attended several NASA Hyperwall talks. **Photo credit:** NASA

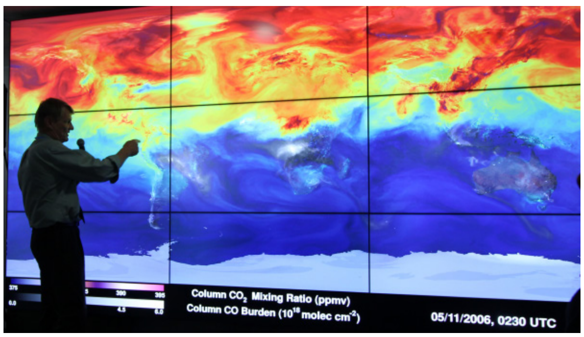

Photo 5. Piers Sellers [NASA's Goddard Space Flight Center] provided a tour of global average column concentrations of atmospheric carbon dioxide and carbon monoxide from January 1, 2006 to December 31, 2006. The visualization was created using data from the 7-km (~4-mi) Goddard Earth Observing System Model, Version 5 (GEOS-5) Nature Run model. **Photo credit:** NASA

Photo 6. Daniel Irwin [NASA's Marshall Space Flight Center] described how NASA develops and supports a large number of Earth-observing missions that study the Earth as a complex system, to understand how it is changing. He also showed a graphic of future NASA Earth-observing missions. **Photo credit:** NASA

COP-20

The next stop on the journey was the 20th Conference of Parties (COP-20) to the United Nations Framework Convention on Climate Change in Lima, Peru, December 1-14, 2014. Each year, the COP meets for two weeks to discuss the state of Earth's climate and how best to deal with future climate change. Hosted by the U.S. Department of State, the *U.S. Center* at COP is a major public outreach initiative to inform attendees about key climate initiatives and scientific research taking place in the U.S. As has been the standard for several years, representatives from NASA, other U.S. government agencies, academic institutions, nongovernmental organizations, private-sector companies, and other stakeholders convene at the U.S. Center to highlight key climate programs and scientific research. The presentations underscored the actions the U.S. is taking to study, understand, and plan effectively for a changing planet.

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Within the U.S. Center, NASA's Hyperwall content highlighted several themes, including Observing Earth from Space, Changes at Earth's Poles, Earth's Ocean and Water Resources, Atmospheric Composition and Aerosols, Human Footprints, and Forests and Biodiversity[5]. **Jack Kaye** [NASA Headquarters—*Associate Director for Research of the Earth Science Division*], **Piers Sellers** [NASA's Goddard Space Flight Center—*Deputy Director for the Sciences and Exploration Directorate*], **Michelle Gierach** [NASA/Jet Propulsion Laboratory—*Research Scientist*], and **Daniel Irwin** [NASA's Marshall Space Flight Center—*Research Scientist*] attended the COP and made presentations using the Hyperwall during the two-week event—see **Photos 5-6**.

AGU Fall Meeting

The Hyperwall's final stop in 2014 was at the American Geophysical Union (AGU) Fall Meeting held in San Francisco, CA, December 15-19. For ten consecutive years, the SPSO

[5] For a full list of shows displayed on the Hyperwall during COP-20, visit *eospso.nasa.gov/sites/default/files/publications/COP-20_2014%20Hyperwall%20Flyer_0.pdf*.

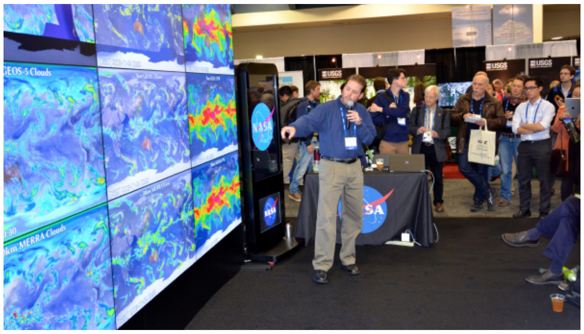

Photo 7. Bill Putman [NASA's Goddard Space Flight Center] revealed never-before-seen results from NASA's GEOS-5 climate model in ultra-high resolution on the dynamic Hyperwall display. **Photo credit:** NASA

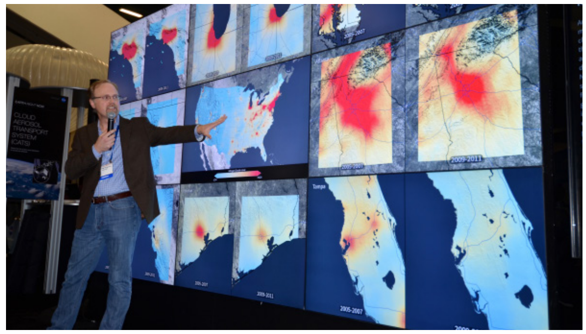

Photo 8. Bryan Duncan [NASA's Goddard Space Flight Center—*Aura Deputy Project Scientist*] showed how observations from NASA's Aura satellite are contributing to policies that are improving air quality conditions in major U.S. cities. **Photo credit:** NASA

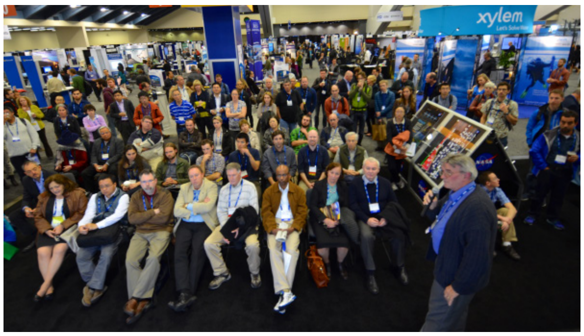

Photo 9. AGU attendees gathered around the Hyperwall to watch **Michael King** [Laboratory for Atmospheric and Space Physics and *Former EOS Project Scientist*] talk about observations from the Moderate Resolution Imaging Spectroradiometer (MODIS). **Photo credit:** NASA

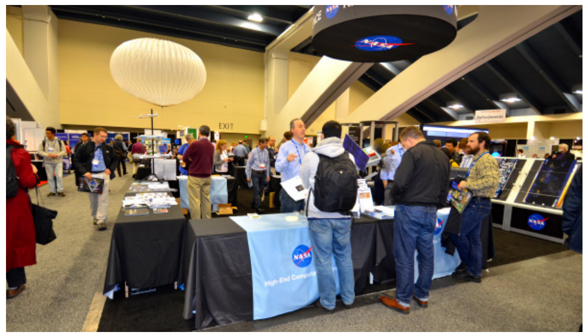

Photo 10. Exhibit visitors enjoyed talking with NASA representatives about different programs, missions, and science results. **Photo credit:** NASA

has coordinated a single NASA exhibit that represents all of the agency's missions and programs in one location. The exhibit featured two visual presentation platforms—the dynamic Hyperwall and a 50" plasma screen—and 15 information stations and kiosks. Conference attendees who visited the exhibit were encouraged to explore the many flavors of NASA's activities, including Earth science, planetary science, and heliophysics.

In total, there were 35 Hyperwall presentations and 39 additional presentations that used the plasma screen—see **Photos 7-9**. The full schedule of events that took place at the exhibit is available online at *eospso.gsfc.nasa.gov/sites/default/files/publications/AGU_2014_Program.pdf*. In addition to these talks, the exhibit offered a wide range of printed materials—including mission brochures, story booklets, fact sheets, lithographs, and the 2015 NASA Science calendar—see **Photo 10**.

Currently, the Hyperwall provides a revolutionary platform for NASA to communicate its science face-to-face in a very personal way—unlike any other space agency in the world—and the SPSO remains dedicated to developing and implementing next-generation communication platforms in the future.

Looking Ahead

NASA's outreach and exhibits allow the agency to represent the breadth and depth of NASA's range of science activities in a single setting and promote NASA's distinctive roles in studying the global atmosphere, oceans and sea ice, land surfaces, ecosystems, the sun, other planets, the universe, and the interactions among these components. Currently, the Hyperwall provides a revolutionary platform for NASA to communicate its science face-to-face in a very personal way—unlike any other space agency in the world—and the SPSO remains dedicated to developing and implementing next-generation communication platforms in the future.

The SPSO will continue to provide and strengthen visibility for the agency; to inspire a new generation of engineers and scientists; to pursue related science, technology, engineering, and math (STEM) activities and educate an interested citizenry; and to represent NASA as the world's leading space and aeronautics research agency. ■

The SMAP Early Adopters Program and the Impact on Prelaunch Research

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Introduction

After over a decade of work and investment, NASA's Soil Moisture Active Passive (SMAP) spacecraft successfully launched on January 31, 2015 on a Delta II rocket from Vandenberg Air Force Base in California, and is now in the next phase of its mission. The period right before launch and the extended postlaunch period (Phase E) is critical for evaluating the value of prelaunch application efforts. It is also important for continuing relationships with end users and early adopters that transition prelaunch research into postlaunch observation studies.

This article will discuss how the SMAP Early Adopter Program took the prelaunch stage of applications into the postlaunch phase. We will discuss how, during the three years before launch, the Early Adopters have given insight to the potential value and impacts of soil moisture data from SMAP. We will briefly explore how the program was started and how it has evolved into a feedback tool for the mission, and created a benchmark for NASA mission applications.

SMAP Mission and Applications Program Strategy

The SMAP mission has been identified as a priority for NASA's Science Mission Directorate through the most recent decadal survey[1]. SMAP is a combined active/passive L-band microwave mission that will deliver global maps of soil moisture content and surface freeze/thaw state—measurements that are critical for terrestrial hydrologic and carbon cycle applications[2].

The SMAP Applications Program has been an integral part of the SMAP mission structure since its early development phases. The overall goal of the SMAP Applications Program is to engage SMAP end users and build broad support for SMAP applications through a transparent and inclusive process. The subgoals of the program are to:

- Define SMAP applied science;
- develop a SMAP *Community of Practice*, i.e., a community of end users and decision makers that understand SMAP capabilities and are interested in using SMAP products in their applications;
- reach out to the *SMAP Community of Potential*—i.e., engage end users who are unfamiliar with SMAP capabilities but have the potential to benefit from SMAP products in their applications;
- identify several *SMAP Targeted Partners*—"Early Adopters" who will partner to optimize their use of SMAP products, possibly even before launch, as part of the SMAP "testbed" activities and SMAP calibration/validation activities;
- provide information about SMAP applications to the *SMAP Community of Support*—i.e., the broader science community—to build support for SMAP applications; and
- facilitate feedback between SMAP Communities and the SMAP Mission and Science Definition Team.

For more details on the SMAP Applications Program, please visit *smap.jpl.nasa.gov/science/applications*. To download the full Applications Program plan, visit *smap.jpl.nasa.gov/files/smap2/SMAP_Apps_Plan_120706.pdf*.

SMAP Early Adopters Program: Where We Are and Where We're Headed

SMAP Early Adopters are defined as those groups and individuals who have a direct or clearly defined need for SMAP-like soil moisture or freeze/thaw data, and who are planning to apply their own resources (e.g., funding, personnel, facilities, etc.) to demonstrate the utility of SMAP data for their particular system or model. SMAP Early Adopters were chosen through a selective process from within the SMAP Working Group Community of Practice (know as the SMAP Applications Working Group, with over 500 members), and are given early access to prelaunch simulated SMAP data products and SMAP calibration/validation products.

The SMAP Early Adopter Program has been recognized by NASA Headquarters as the most valuable component of the SMAP Applications Program—and the SMAP mission is the first NASA decadal survey mission to implement an Early Adopter Program. The goal of the SMAP Early Adopter Program (which is an unfunded activity) is to facilitate feedback on SMAP products *prelaunch*, and to accelerate the use of SMAP

[1] The 2007 National Research Council (NRC) Decadal Survey report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, provides the basis for the future direction of NASA's space-based Earth observation system.
[2] To learn more about the SMAP mission, read "SMAP: Mapping Soil Moisture and Freeze/Thaw State from Space" on pp. 14-19 of this issue.

Figure 1. This map shows the distribution of SMAP Early Adopters. Red outlined dots show the Early Adopter Organization's location. These Early Adopters all have a global application defined in their research effort. Black outlined dots show Early Adopters with applications in Africa, the Middle East, and the North Pole. **Image credit:** Susan Moran, SMAP Science Team, U.S. Department of Agriculture Agricultural Research Service

products, *postlaunch*. These goals are achieved by providing specific support to Early Adopters who commit to engage in applied research. The program combines a communication and outreach strategy from workshops, focus sessions, and tutorials that impact research, communication, and feedback from the Applications Working Group. This approach creates a sophisticated team of researchers who can qualify and quantify the impact of SMAP mission products in societally relevant applications for weather, agriculture, health, hazards (e.g., flooding and landslides), transportation, and national security.

The focus of Early Adopter research is to understand future applications of SMAP products and to address challenges with data access and processing prior to launch. The hope is that these "pioneering" efforts will make it easier for the broad user community to begin to use SMAP data. In April 2014, during the third SMAP Application Workshop in Boulder, CO, all of the SMAP Early Adopters presented their research results to the SMAP user community. The feedback is helping NASA's Distributed Active Archive Centers (DAACs) and the SMAP mission mold how SMAP data are delivered in the future.

The original intent of the Early Adopter Program was to get a handful of volunteers to use SMAP simulated data and provide the mission science team with an understanding of how SMAP data would be used prior to launch, and offer feedback on the societal impact SMAP data would have after the data were available.

As of today, there are 38 Early Adopters and 7 potential adopters who have pending applications—see **Figure 1**. Each Early Adopter addresses one of seven Applications: Weather and Climate Forecasting, Droughts and Wildfires, Floods and Landslides, Agriculture Productivity, Human Health, National Security, and Commercial Insurance—see **Tables 1-7**. From 2011-2012, 19 Early Adopters signed a Statement of Activity (SOA), agreeing to "engage in prelaunch research that will enable integration of SMAP data after launch in their application; complete the project with quantitative metrics prior to launch; and take a lead role in SMAP applications research, meetings, workshops, and related activities." These Early Adopters are marked with an asterisk in Tables 1-7.

In 2012 (a little over two years before launch), the Early Adopter Program transitioned to an "Application for Access to Prelaunch SMAP Simulated and Calibration/Validation Data" rather than an SOA. In this way, Early Adopters agreed only to "engage in prelaunch research that will enable integration of SMAP data after launch in their application, and to provide feedback to the SMAP project upon request concerning their experience in using the data." These Early Adopters are marked with a diamond in Tables 1-7. This removed the requirement for the prelaunch Early Adopter results to have fixed, quantifiable results constrained by SMAP-like data, and gave new Early Adopters the option to use qualifiable results as a valid reporting metric.

The Applications Team has tracked all Early Adopters' progress with quarterly telecons (followed by an email summary) and quad charts for each Early Adopter, outlining the objectives, methodology, status, schedule, and issues. Based on those deliverables, it is clear that the 2011/2012 Early Adopters have met and exceeded prelaunch expectations, and the Early Adopters from 2013 onward are making progress and contributing to the mission.

The SMAP Applications Program expects to see improvements across many applications but especially those focused on weather forecasting, drought and flood prediction, and agriculture productivity. In addition, the program has learned over the past four years of prelaunch applications research that the expectations of the adopters can be easily underestimated. For example, the program anticipates that the Early Adopters will make discoveries that the SMAP science team did not expect, that there will be new science questions that develop from Early Adopter efforts, and that there will be unique and innovative ways people use SMAP data because of the feedback from and lessons learned by the Early Adopters. As a result, the use of SMAP data by Early Adopters will help demonstrate the value of remote sensing in decision processes that impact human lives.

Table 1. Weather and Climate Forecasting Early Adopters

Weather and Climate Forecasting	
Researcher(s)	**Organization(s)**
* Stephane Bélaird	Meteorological Research Division, Environment Canada (EC)
* Lars Isaksen and Patricia de Rosnay	European Centre for Medium-Range Weather Forecasts (ECMWF)
* Xiwu Zhan, Michael Ek, John Simko, and Weizhong Zheng	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP); NOAA National Environmental Satellite Data and Information Service (NESDIS)
* Michael Ek, Marouane Temimi, Xiwu Zhan, and Weizhong Zheng,	NOAA NCEP; NOAA NESDIS; City College of New York (CUNY)
* John Galantowicz	Atmospheric and Environmental Research, Inc. (AER)
◊ Jonathan Case, Clay Blankenship, and Bradley Zavodsky	NASA's Short-term Prediction Research and Transition (SPoRT) Center

Table 2. Droughts and Wildfire Early Adopters

Droughts and Wildfires	
Researcher(s)	**Organization(s)**
* Jim Reardon and Gary Curcio	U.S. Forest Service (USFS)
* Chris Funk, Amy McNally, and James Verdin,	U.S. Geological Survey (USGS); University of California Santa Barbara
◊ Brian Wardlow and Mark Svoboda	Center for Advanced Land Management Technologies (CALMIT); National Drought Mitigation Center (NDMC)
◊ Uma Shankar	The University of North Carolina at Chapel Hill—Institute for the Environment

Table 3. Floods and Landslide Early Adopters

Floods and Landslides	
Researcher	**Organization(s)**
* Fiona Shaw	Willis Group's Global Analytics
* Rafael Ameller	StormCenter Communications, Inc.
* Kashif Rashid	United Nations World Food Programme
◊ Konstantine Georgakakos	Hydrologic Research Center
◊ Steven Quiring	Texas A&M University
◊ Luca Brocca	Research Institute for Geo-Hydrological Protection, Italian Department of Civil Protection

* = Early Adopters from 2011–12
◊ = Early Adopters from 2013

Table 4. Agricultural Productivity Early Adopters

Agricultural Productivity	
Researcher(s)	**Organization(s)**
* Catherine Champagne	Agriculture and Agri-Food Canada (AAFC)
* Zhengwei Yang and Rick Mueller	U.S. Department of Agriculture (USDA) National Agricultural Statistical Service (NASS)
* Amor Ines and Stephen Zebiak	International Research Institute for Climate and Society (IRI), Columbia University
* Jingfeng Wang, Rafael Bras, Aris Georgakakos, and Husayn El Sharif	Georgia Institute of Technology (GT)
* Curt Reynolds	USDA Foreign Agricultural Service (FAS)
◊ Alejandro Flores	Boise State University
◊ Barbara Minsker	University of Illinois, sponsored by John Deere Inc.
◊ Lynn Torak	USGS, Georgia Water Science Center
◊ Kamal Labbassi	Chouaib Douakkali University, Faculty of Sciences (CDU FS); Moroccan Association of Remote Sensing of the Environment (MARSE)

Table 5. Human Health Early Adopters

Human Health	
Researcher(s)	**Organization(s)**
* Hosni Ghedira	Masdar Institute of Science and Technology
* Kyle McDonald and Don Pierson	CUNY; NOAA Cooperative Remote Sensing Science and Technology Center (CREST), New York City Department of Environmental Protection
◊ James Kitson, Andrew Walker, and Cameron Hamilton	Yorkshire Water
◊ Luigi Renzullo	Commonwealth Scientific and Industrial Research Organization (CSIRO)

Table 6. National Security Early Adopters

National Security	
Researcher(s)	**Organization(s)**
* John Eylander and Susan Frankenstein	U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL)
* Gary McWilliams, George Mason, Li Li, Andrew Jones, and Maria Stevens	Army Research Laboratory (ARL); U.S. Army Engineer Research and Development Center (ERDC) Geotechnical and Structures Laboratory (GSL); Naval Research Laboratory (NRL); and Colorado State University (CSU)
◊ Kyle McDonald	CUNY
◊ Georg Heygster	Institute of Environmental Physics, University of Bremen, Germany
◊ Lars Kaleschke	Institute of Oceanography, University of Hamburg
◊ Jerry Wegiel	Air Force Weather Agency

* = Early Adopters from 2011–12
◊ = Early Adopters from 2013

Table 7. Other general Early Adopter topics

General	
Researcher(s)	**Organization**
◊ Srini Sundaram	Agrisolum Limited
◊ Thomas Harris and Dave Hulslander	Exelis Visual Information Solutions
◊ Kimberly Peng	Africa Soil Information Service (AfSIS), Center for International Earth Science Information Network (CIESIN)

◊ = Early Adopters from 2013

Societal Impacts

The societal impacts of the Early Adopter research will be assessed in the postlaunch years of the SMAP mission. Shortly after SMAP launches, the SMAP Applications coordinators will host a *SMAP Impact Workshop* that will identify the benchmarks of all Early Adopter research projects. This workshop will provide a baseline for all Early Adopter projects so that a quantifiable or qualifiable value can be attained after SMAP data products are used by the adopters.

Impact on Prelaunch Research and NASA's Applied Science Program

The SMAP Early Adopters Program has grown beyond what the mission expected. The access to prelaunch data was the initial "carrot" for the program. The thought was that the early data access would provide incentives for sophisticated senior researchers to come forward and provide the mission some insight on the "fit" of the data. Because prelaunch data are not real observations, they can only be used to test systems and processes rather than validate information. Thus, the expectation was that there would be very limited response to this opportunity. As it turns out, quite the opposite was found, and the responses were overwhelming. The team quickly realized that the prelaunch data were not the "carrot" to the Early Adopter Program. Through communication with Early Adopters and the SMAP Science Team, the Applications Program quickly learned that the access to the prelaunch data and the opportunity to participate in thematically driven mission workshops provided invaluable exposure to the Early Adopters. However, the main reason the Early Adopters Program grew beyond expectations was because of the relationships the program allows the adopters and the Science Team to develop with one another.

According to Early Adopter feedback, the inside access to the Science Team and the opportunity to share thoughts and feedback on specific applications research was the most valued part of the program. Coincidentally, the Science Team also expressed how much they valued the insight of the Early Adopters and how the feedback from the Early Adopters allowed the Science Team a unique and expanded perspective on how SMAP data will be used.

The feedback between the Early Adopters and the Science Team has become so important that the SMAP mission has extended the program through the life of the mission, welcoming researchers to apply through 2018.

Conclusion

The Early Adopter Program demonstrates that there is a deep-rooted drive among several communities to ensure that science touches lives. Early Adopters present science from a perspective we can all identify with and see the impacts of soil moisture data in a context that makes it personal. Making science applications personal helps demonstrate that satellite data provide value to society (better health, efficiency, and cost savings). The lessons learned from the program are shared with the Science Team and other researchers so others can reap the same reward of having a more profound impact on the future with their research.

The clear value of the Early Adopter Program is further demonstrated by the decision to implement similar activities across other NASA missions (future missions as well as those currently in operation). ■

Summary of 2014 GOFC-GOLD Fire Implementation Team Meeting

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Introduction

The Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) program provides an international forum to exchange information, coordinate observations and data handling, and provide a framework to establish necessary long-term monitoring systems. The GOFC-GOLD Fire Mapping and Monitoring Theme is aimed at refining and articulating relevant international observational requirements and making the best possible use of fire data products from existing and future satellite observing systems for fire management, policy decision-making, and global-change research. GOFC-GOLD Fire, in a joint effort with the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV), Land Product Validation (LPV) subgroup, is pursuing the coordinated validation of fire products by standardized protocols.

The GOFC-GOLD Fire Implementation Team (IT) Meeting was held July 29-31, 2014; the National Oceanic and Atmospheric Administration's (NOAA) Center for Weather and Climate Prediction (NCWCP) hosted the meeting in College Park, MD. The SysTem for Analysis, Research and Training (START) and the University of Maryland, College Park (UMd) cosponsored the meeting, the overall goal of which was to promote collaboration among U.S. and international researchers focusing on satellite remote sensing of fires. The approach used was to review current status, recent developments, and future prospects of satellite-based fire monitoring and science. Specifically, the meeting focused on reviewing the new and planned satellite fire sensing systems, e.g., the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership (NPP) platform and planned for future Joint Polar Satellite System (JPSS) satellites, European Space Agency (ESA)'s Sentinel missions, and the Deutsches Zentrum für Luft und Raumfahrt's (DLR) [German Space Agency] Technologieerprobungsträger-1 (TET-1) Technology Experiment satellite.

The presentations summarized here, can be downloaded from *gofc-fire.umd.edu/meeting/static/GOFC_Fire_IT_2014/index.php*.

Meeting Summary

After a welcome by **Ivan Csiszar** [NCWCP], **Chris Justice** [UMd] presented the objectives of the meeting and an overview of the evolution of fire monitoring from space, from its start in the 1980s to the present. He recounted the initial efforts to develop algorithms and global datasets at 1-km (~0.6-mi) resolution from the Advanced Very High Resolution Radiometer (AVHRR) onboard NOAA Polar-Orbiting Environmental Satellites (POES) and the

2014 GOFC-GOLD Fire Implementation Team Meeting participants. **Photo credit:** Kris Lasko, UMd major advances in fire monitoring achieved by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Earth Observing System (EOS) satellites, Terra and Aqua. Justice highlighted the various internationally generated data products and field campaigns associated with advancing fire monitoring and our understanding of fire emissions over the years, and concluded with the operational outlook for the Suomi NPP VIIRS and future JPSS, the Geostationary Operational Environmental Satellite (GOES)-R, and the Sentinels.

Ivan Csiszar presented information on the Suomi NPP mission and the VIIRS fire detection capabilities, on behalf of **Mitch Goldberg** [NOAA—*JPSS Program Scientist*], who was unable to attend the meeting. He stated that VIIRS incorporates fire-sensitive channels, including a dual-gain, high-saturation temperature, 4-µm channel, enabling active fire detection and characterization.

Louis Giglio [UMd] described the 750-m (~2460-ft) VIIRS active fire product, which is based on VIIRS's 16 moderate-resolution (750-m) "M-bands," and is one of the standard Environmental Data Records generated by the NOAA JPSS ground system. This fire product builds on an earlier *Collection 4* version of the MODIS fire algorithm. The VIIRS active fire product has shown more fire detections than MODIS—due to improved spatial resolution. Further development is in progress to ensure high-quality VIIRS fire products that extend the MODIS data record.

Wilfrid Schroeder [UMd] showcased the emerging 375-m (~1230-ft) VIIRS "I-band" product. He described the potential of 375-m middle- and thermal-infrared imagery data in fire detection, noting small, but variable, commission errors (< 1.2%) for nominal-confidence fire pixels. These data improve detection performance as compared to the VIIRS 750-m baseline fire product. The VIIRS 375-m fire data resulted in superior mapping capabilities with improved consistency of fire perimeter delineation as compared to current MODIS fire data.

Mark Ruminski [NOAA] presented details on the NOAA Hazard Mapping System (HMS). The HMS was developed in 2001 by the National Environmental Satelllite, Data, and Information Service (NESDIS) as an interactive tool to identify fires and the smoke emissions over North America in an operational environment. The HMS incorporates data from two geostationary satellites (GOES-East/West) and seven polar-orbiting systems (Terra, Aqua, NOAA-15, -18, and -19, and METOP–A and -B[1]). Automated fire detection algorithms are employed for each satellite sensor, which are then addressed by analysts, who apply quality control procedures for automated fire detection and then manually added smoke plume detection. Further, determination of the smoke concentration values is aided by the GOES Aerosol and Smoke Product (GASP). More details about the fire and smoke product can be found at *www.ospo.noaa.gov/Products/land/hms.html*.

Olivier Arino [ESA, Italy] gave an update on the Sentinel program. Launched in April 2014, Sentinel-1A is a polar-orbiting, day-and-night radar imaging mission with a 5-m (~16-ft) ground resolution and 12-day repeat cycle at the equator, designed for land and ocean services. He showcased the potential of Sentinel-1A data for deforestation studies in Brazil, and vegetation regeneration after burn scarring in Greece. He also presented the details on the instrument characteristics of the planned Sentinels 2 through 6[2].

Emilio Chuvieco [University of Alcala, Spain] reported on the new ESA-supported Fire-Climate Change Initiative (CCI) burnt-area product that relies on Envisat's MEdium Resolution Imaging Spectrometer (MERIS) data and an algorithm that merges data from three sources: MERIS, Satellite Pour l'Observation de la Terre (SPOT) Vegetation, and Along Track Scanning Radiometer (ATSR[3]). The spatial resolution of the gridded product is 0.5 x 0.5°, with information on total burned area, percent observed area, number of patches, and burned area of each land cover. The burned area pixel product includes information on the date of detection, confidence level, percent observed areas, and burned cover.

Martin Wooster [Kings College London (KCL), U.K.] provided an update on near-real-time (NRT) geostationary fire products. Currently, the Fire Radiative Power (FRP) product from the Meteosat Second Generation satellite's Spinning Enhanced Visible and Infrared Imager (SEVIRI) data covering Europe, Africa, and parts of South America is available via *ftp* from the Land Surface Analysis Satellite Application Facility (LSA SAF) website (*landsaf.meteo.pt*). Also, the NRT GOES FRP product over North and South America is available on request from KCL. He stated that the MODIS FRP datasets have uncertainty of 26.6% at one standard deviation, and the uncertainties are driven by fire location; thus one should be cautious when estimating the emissions from FRP. He also discussed the Global Fire Assimilation System (GFAS) that provides global emissions of biomass burning at 0.5° and 1° resolution (*www.gmes-atmosphere.eu/about/project_structure/input_data/d_fire*). He outlined plans for EUMETSAT's Meteorological Satellite (Meteosat)

[1] METOP is an operational meteorological satellite system operated by the European Organisation for the Exploitation of Meterological Satellites (EUMETSAT).

[2] To learn more about the plans for Sentinel read "An Overview of Europe's Expanding Earth-Observing Capabilities" in the July-August 2013 issue of *The Earth Observer* [**Volume 25**, **Issue 4**, pp. 4-15].

[3] ATSR flies onboard SPOT-4.

Third Generation Imager and Sounder, to be launched in the 2016-18 timeframe, and the NOAA GOES-R, to be launched in 2015.

Peter Roohr [NOAA] addressed current fire-weather research and challenges. He explained the National Weather Service's (NWS) vision for developing high-resolution fire-weather information and services in close collaboration with agency partners. Developing such services has benefits to the user community in minimizing firefighter fatalities due to unpredicted fire behavior, cost savings with more efficient use of resources, better understanding of growth of existing fires to prevent loss of life, and other uses. He called for more research to address information gaps to enhance the fire-weather systems such as limited observations and measurements near fires, improved high-resolution weather forecasts, and smoke prediction. To address the above concerns, Roohr suggested strong partnerships with land-management agencies through joint fire science programs, integrating VIIRS data into coupled fire-weather models, and improved funding for NWS.

Eckehard Lorenz [DLR, Germany] provided an update on TET-1, the first satellite of the FireBird constellation of microsatellites ("CubeSats"). TET-1 is a technology demonstration microsatellite that was launched in July 2012. The TET-Bus is based on the BIspectral Infrared Detection (BIRD) satellite, with a primary goal of sensing "hot phenomena" such as wildfires, volcanoes, gas flares, and industrial hotspots. Notably for its size, the satellite is equipped with cameras with 42-m (~138-ft) ground pixel size in the red, green, and near infrared spectral range; and 370-m (~1214-ft) ground pixel size in the mid- and thermal-infrared, with a swath of 185 km (~115 mi). The satellite can be pointed toward a target to enhance observation frequency. The second satellite in the series, Berlin infraRed Optical System (BiROS), is scheduled for launch in 2015 and will deliver quantitative information on FRP at a spatial resolution of 350 m (~1148 ft).

David Roy [South Dakota State University] discussed the status of Landsat-8, with emphasis on improvements over Landsat 7's capabilities in terms of scenes-per-day global coverage, higher quantization, and improved geolocation capabilities. These improvements make Landsat-8 more useful for detecting changes in surface properties than its predecessor. Roy stated that efforts are underway to generate surface reflectance products and stressed on the need for generation of "higher-level" 30-m (~98-ft) Landsat products—similar to those generated for MODIS. He provided details on the Web-Enabled Landsat Data Record (WELD) project, where Landsat data are being processed at a global scale to provide weekly, monthly, seasonal, and annual products. More details can be found at *globalmonitoring.sdstate.edu/projects/weldglobal*.

Mark Carroll [NASA's Goddard Space Flight Center/Science Systems and Applications, Inc.] presented details on the Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER) project that brings together disparate information necessary to address post-fire rehabilitation through a decision support system. RECOVER uses cloud computing capabilities to automatically and rapidly gather Earth observational data, derived decisions, and historic biophysical layers. The project is being designed in close collaboration with the U.S. Department of Interior's Bureau of Land Management and the Idaho Department of Lands.

Chris Justice gave an update on the GOFC-GOLD Fire program, which has been providing inputs on the Group on Earth Observations (GEO) Wildfire Task (*DI-01-C4*). This task informs risk management and disaster reduction applications; supports international meetings and partner program activities; helps to coordinate regional networks and workshops; and performs outreach and communication through the website (*gofc-fire.umd.edu*). Justice highlighted priorities for GOFC-GOLD Fire IT for the coming years, which include: working with interagency and international partners to incorporate operational fire-monitoring capabilities into upcoming missions; providing data and product continuity through NOAA/ESA/NASA—including NRT data access; promoting space agency coordination of global moderate-resolution data processing and access (e.g., from Landsat-8 and Sentinel 2); continuing to advocate for meteorological agency support to establish a Global Geostationary Fire Network; implementing and providing regional calibration of operational Global Fire Early Warning Systems; working on Global Burned Area Products and Validation (Stage 3); and garnering support for the Regional Fire Networks and developing capacity building programs on the use of satellite fire data through START and NASA.

Johann Goldammer [Freiburg University, Germany] described international cooperation and coordination for wildland fire management through the Global Wildland Fire Network (GWFN). Objectives include developing common international principles for fire management; a global and regional set of agreements on transboundary cooperation in fire management; sharing resources in capacity building in fire management, including cooperation in wildfire emergency response; and establishing international policies to address global change and fires. He called for more active involvement of GOFC-GOLD regional Fire IT capabilities to develop NRT fire early warning and monitoring information and establishing joint activities with regional fire management resource centers to address fire concerns.

Luigi Boschetti [University of Idaho] discussed the GOFC-GOLD sourcebook for Reducing Emissions from Deforestation and forest Degradation Plus (REDD+) in developing countries activities. The sourcebook is currently being updated in collaboration with the United Nations Food and Agriculture Organization (FAO) to include training material with country examples and lectures. He stressed the need for more improvements in data formats and distribution systems, including use of 30-m (98-ft) Landsat data to estimate emissions through international funding.

Kevin Tansey [University of Leicester, U.K.] presented updates on the development of the Global Climate Observing System (GCOS) 2016 Implementation Plan. The inputs to the new GCOS plan are several, e.g., the 2013/2014 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), the 2011 World Climate Research Program (WCRP) conference, the 2013 Stratosphere–troposphere Processes And their Role in Climate (SPARC) data workshop, the 2014 EUMETSAT/WCRP climate symposium, and GCOS/WCRP panel assessments. Specific to the fire datasets, Tansey stated that a review of user requirements in the context of GCOS was recently published[4]. He highlighted new issues for the implementation plan, such as: representation of fire in IPCC-class models; validation and uncertainty characterization of fire products; improved fire-product spatial resolution and accuracy; and fire-product trend analysis, including a rolling review of requirements.

The next three presentations focused on Global Fire Early Warning Systems. **Bill de Groot** [Natural Resources Canada] presented new developments to the Canadian Global Fire Early Warning System, which is being refined to include fire behavior characteristics, e.g., spatial rainfall, fire radiative energy (indicating fuel consumption and emissions), fire intensity from fuel consumption, and rate of fire spread from FRP and fuel-load-affecting emissions. **Tim Brown** [Desert Research Institute, Nevada] discussed meteorological data for fire danger products, stating that *Version 2* of the Climate Forecast System is being developed for use in early warning systems; the new version features 1° horizontal resolution and a Global Forecast System with 13-km (~8-mi) resolution. **Jesus Ayanz** [Joint Research Center (JRC), Italy], gave an update on the Global Wildfire Information System (GWIS), which builds on earlier work of the European Forest Fire Information System (EFFIS), developed by JRC in close collaboration with the fire services in several European countries. This system provides "harmonized" information on forest fires in Europe, and is being expanded to global coverage as the GWIS. Currently, GWIS is included in the GEO Work Plan, and integrating the Copernicus web services with GWIS is being planned.

Krishna Vadrevu [UMd] presented an overview of the biomass burning focus area—with contributions from **Guido van der Werf** [Vrije Universiteit, Netherlands] who could not attend the meeting. Specific issues with respect to NRT estimates of emissions include FRP-to-fire radiative energy conversion, fuel consumption estimation, and variability in emission factors. He highlighted the need to address emissions from small fires by employing higher-spatial-resolution data and using the Landsat burned-area archive to validate new approaches. Vadrevu also discussed satellite monitoring of pollutants from biomass burning events, noting that FRP-Aerosol Optical Depth relationships in agricultural systems are weak and need more investigation. His results highlighted the need for more work on small-mode fraction products and Greenhouse gases Observing SATellite (GOSAT) carbon dioxide (CO_2) data for fire emission studies. On the topic of fire emissions, **Shobha Kondragunta** [NOAA] provided an update on the global biomass burning emissions product that uses geostationary datasets from multiple satellites to estimate emissions. The emission product can be downloaded from *satepsanone.nesdis.noaa.gov/pub/FIRE/GBBEPx*.

Several presentations describing GOFC-GOLD Regional Networks around the world came next. Included were representatives from South Africa, Latin America, Mexico, Southeast Asia, and the Balkan regions. **Philip Frost** [Council for Scientific and Industrial Research, South Africa] described the status of the Southern Africa Fire Network (SAFNET), stating that a new MODIS direct-broadcast reception station will be installed in Kenya, and that the Advanced Fire Information System (AFIS) has been enhanced with an Android application to provide fire alerts. **Alberto Setzer** [Instituto Nacional de Pesquisas Espaciais (INPE), Brazil] described the Red Latinoamericana de Teledetección e Incendios Florestales (RedLaTIF), stating that INPE's fire system is helping to locate illegal deforestation and burning in Amazonia, and that there is a need to refine global fire products through ground validation, since most of them underestimate burned area for Brazil. **Isabel Cruz** [Comisión Nacional para el conocimiento y uso de la Biodiversidad (CONABIO), Mexico] described how CONABIO is developing a fire early warning system to include fire detections from VIIRS data. **Krishna Vadrevu** stated that the Southeast Asia Regional Research and Information Network (SEARRIN) network is quite active and has been organizing meetings every year jointly with Japan's National Institute of Environmental Studies (NIES). The latest

[4] Mouillot, F., Schultz, M. G., Yue, C., Cadule, P., Tansey, K., Ciais, P., and Chuvieco, E. (2014). "Ten years of global burned area products from spaceborne remote sensing—A review: Analysis of user needs and recommendations for future developments," *International Journal of Applied Earth Observation and Geoinformation*, *26*, 64-79.

meeting results can be found at *gofc-fire.umd.edu/meeting/static/Vietnam_workshop_2014/index.php*. **Ioannis Gitas** [Aristotle University of Thessaloniki, Greece] reported that the Balkan Network is currently developing a Balkan Wildland Fire Observatory, useful for fire monitoring in the region. He also noted that the tenth European Association of Remote Sensing Laboratories Fire Special Interest Group meeting is planing to meet in Cyprus in October 2015.

Sylvia Wilson [U.S. Geological Survey] presented information on the SilvaCarbon program, which is focused on REDD+ and a contribution to the GEO Global Forest Observation Initiative (GFOI). SilvaCarbon partners with developing countries to improve monitoring of forest and terrestrial carbon fluxes; improve understanding of methodologies and collection and dissemination of data; and coordinate U.S. science, innovation, and technical expertise. More information about the SilvaCarbon program can be found at *egsc.usgs.gov/silvacarbon/node/30.html*.

Vincent Ambrosia [NASA's Ames Research Center] described the NASA Applied Sciences Wildfire Program and the Research Opportunities in Space and Earth Sciences (ROSES) 2011 selections and the nine projects selected for Phase-2 implementation with three-year funding. He also discussed the NASA airborne Autonomous Modular Sensor (AMS), transferred to the U.S. Foreign Service (USFS) National Infrared Operations (NIROPS) and USFS Remote Sensing Applications Center (RSAC) for operational support. Further details on the AMS were presented by **Everett Hinkley** [U.S. Department of Agriculture (USDA)] that can be found at *nirops.fs.fed.us/ams* and implemented through USDA's Forest Service Remote Sensing Applications Center's (RSAC) program.

Tim Lynham [Canadian Forest Service] presented details on the New Infrared Sensor Technology (NIRST) wildfire-monitoring tool, highlighting the low cost and excellent fire detection with a 350-m (1148-ft) spatial resolution. Measurment limitations include mid-infrared calibration, accuracy concerns regarding FRP, and inability to measure subpixel changes in radiances. He also presented details on the Polar Communications and Weather (PCW) Mission Molniya Orbit, which can be found on the GOFC-GOLD Fire IT website (*gofc-fire.umd.edu/meeting/static/GOFC_Fire_IT_2014/index.php*).

Conclusion

The GOFC-GOLD Fire IT meeting was successful in bringing researchers together to review progress and recent developments in satellite fire-sensing systems, including calibration and product validation. The GOFC-GOLD Fire IT will continue to as well as promoting open data policies and free sharing of Earth-observations data for scientific research; as well as promoting generation of higher-order fire products from different satellites. The Team will also support regional fire networks and develop capacity-building programs on the use of satellite fire data; coordinate with international agencies to develop best practices and protocols for fire observations in support of measuring and understanding essential climate variables, REDD, and international conventions; and facilitate satellite fire data outreach and dissemination activities. ■

SMAP: Mapping Soil Moisture and Freeze/Thaw State from Space

continued from page 19

Human Health

Improved seasonal soil moisture forecasts using SMAP data will directly benefit famine early warning systems, particularly in sub-Saharan Africa and South Asia, where hunger remains a major human health factor and because the population harvests its food from rain-fed agriculture in highly monsoonal (i.e., seasonal) conditions. Indirect benefits will also be realized, as SMAP data will enable better weather forecasts that lead to improved predictions of heat stress and virus-spreading rates. In addition, SMAP will benefit the emerging field of *landscape epidemiology* (identifying and mapping vector habitats for human diseases such as malaria), where direct observations of soil moisture can provide valuable information on vector-population dynamics.

Summary

The SMAP mission will bring new data and consequent new perspectives on the freeze/thaw state of soil, with spatial resolution far greater than what has come before. The impacts on our understanding of terrestrial processes and phenomena will be large, as will practical, applications-level benefits.

Given the mission requirements, SMAP's unique data will provide new perspectives on our planet for years to come. For more details about SMAP, refer to the SMAP Handbook at *smap.jpl.nasa.gov/files/smap2/SMAP_Handbook_FINAL_1_JULY_2014_Web.pdf*. ■

Joint CERES, ScaRaB, and GERB Science Team Meeting

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Norman Loeb, NASA's Langley Research Center, norman.g.loeb@nasa.gov

Overview

The fall 2014 Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held October 7-10, 2014, in Toulouse, France. The meeting was held jointly with science team meetings for the Scanner for Radiation Budget (ScaRaB[1]) and Geostationary Earth Radiation Budget (GERB[2]). **Remy Roca** [Centre National de la Recherche Scientifique (CNRS[3])—*ScaRaB Principal Investigator*] hosted the meeting. The major objectives of the meeting were to review the status of CERES[4], ScaRaB, and GERB instruments and data products, and to intercompare these three Earth radiation-measuring instruments.

[1] ScaRaB flies onboard the Megha-Tropiques, a joint mission between the Indian Space Research Organisation (ISRO) and French Centre National d'Études Spatiales (CNES).

[2] GERB flies onboard the European Organisation for the Exploitation of Meteorological Satellites, (EUMETSAT) Meteosat Second Generation (MSG-1) satellite. There have been three GERB launches, the most recent being GERB-3 onboard MSG-3 (Meteosat-10) in 2013—which failed four months later. GERB-4 is planned for launch in July 2015 onboard MSG-4 (Meteosat-11).

[3] CNRS is also known as the National Center for Scientific Research.

Meeting presentations can be downloaded from the CERES website by clicking the *CERES Meetings* button on the left navigation bar at *ceres.larc.nasa.gov.*

Programmatic and Technical Presentations

The agenda for the first day and the morning of the second day consisted of a series of technical presentations by members of the CERES, ScaRaB, and GERB science teams; the ScaRaB and GERB technical presentations are listed in **Tables 1 and 2**. The CERES science team technical presentations are described briefly here.

[4] Operational CERES instruments currently fly onboard NASA's Terra, Aqua, and the joint NASA/National Oceanic and Atmospheric Administration (NOAA) Suomi National Polar-orbiting Partnership (NPP) satellites.

Table 1: ScaRaB technical presentations from day one (Tuesday, October 7).

Speaker [Affilation]	**Topic**
Michel Capderou [Laboratoire de Météorologie Dynamique (LMD)]	The Megha-Tropiques orbit: consequence for Earth radiation studies
Michel Dejus [CNES]	The ScaRaB instrument onboard Megha-Tropiques
Olivier Chomette [LMD]	Validation of the ScaRaB radiance
Patrick Roberanto [LMD]	Validation of the ScaRaB flux

Table 2: GERB technical presentations from day two (Wednesday, October 8).

Speaker	**Topic**
Helen Brindley [Imperial College, London]	GERB project overview
Jacqui Russell [Imperial College]	GERB project and instrument status
James Rufus [Imperial College]	GERB operations report
Jacqui Russell [Imperial College]	GERB calibration report
Andy Smith and **Martin Bates** [Both from Science and Technology Facilities Council's Rutherford Appleton Laboratory (RAL) Space]	GGSPS status report
Nicolas Clerbaux [Royal Meteorological Institute of Belgium (RMIB)]	RMIB On Line Shortterm Service (ROLSS) status report
Edward Baudrez [RMIB]	GERB Level-2 Binned Average Rectified Geolocated (BARG)/High Resolution (HR) filled products and release
Helen Brindley [Imperial College]	Future plans and product development

Norman Loeb [NASA's Langley Research Center (LaRC)—*CERES Team Leader*] presented the *State of CERES* and discussed the objectives of the joint workshop. He provided an overview of CERES data processing and the status of software deliveries for Terra and Aqua *Edition 4* processing and Suomi NPP *Edition 1* processing. Loeb then described long-term plans for the CERES team, which include working with the NASA Goddard Modeling Assimilation Office (GMAO) on next-generation meteorological assimilation used in CERES processing, modernizing the production code, validating CERES Edition 4 products, placing Visible Infrared Imaging Radiometer Suite (VIIRS) radiances on the same radiometric scales as the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Aqua, ensuring a seamless transition between Earth radiation budget products on different satellites, and preparing production codes for CERES Flight Model-6 (FM-6) onboard the Joint Polar Satellite System-1 (JPSS-1) satellite, currently scheduled for launch in 2017.

Kory Priestley [LaRC] presented the *CERES Flight Model 6 and Radiation Budget Instrument (RBI) Status.* He summarized the past and future activities for CERES FM-6 and provided an overview of the JPSS-1 satellite. He then discussed the status of the Radiation Budget Instrument (RBI[5]) project, which builds upon the partnerships between NASA and the National Oceanic and Atmospheric Administration (NOAA), with the main science goal of continuing CERES measurements from the last two decades in support of global climate monitoring.

Susan Thomas [Science Systems and Applications, Inc. (SSAI)] provided the *CERES FM1–FM5 Instrument Status*. She presented the calibration status of the Suomi NPP/CERES FM-5 instrument, and the gain factors for FM-5, delivered for Suomi NPP Edition 1 processing. Instrument gain and spectral response functions for FM1-FM4 have been delivered through December 2013 for Terra/Aqua *Edition 4* processing. She also reported that the daytime longwave trend differences between ocean and land scenes in Aqua measurements were corrected in Edition 4 products.

Patrick Minnis [LaRC] presented the *CERES Clouds Working Group Report*. He reported on comparisons between Aqua Edition 4 and Suomi NPP Edition 1. He also presented comparisons between imager cloud retrievals from CERES and from NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO). Minnis reported that differences in cloud properties between VIIRS onboard Suomi NPP and MODIS onboard Aqua are mostly over polar regions—highlighting the need to refine the VIIRS polar cloud mask in *Edition 2*.

[5] In May 2014, RBI is scheduled for flight onboard JPSS-2.

Wenying Su [LaRC] presented the *CERES Edition 4 Angular Distribution Models (ADM)* report. She provided an overview of the CERES next-generation ADMs and presented validation results for CERES shortwave (SW) and longwave (LW) fluxes. For regional fluxes, top of atmosphere (TOA) flux errors due to ADM uncertainties are assessed using a direct integration method. Instantaneous TOA flux errors are evaluated using a multiangle flux consistency test using MODIS and along-track CERES measurements. She also addressed the flux uncertainty from scene identification error, using CALIPSO observations.

David Kratz [LaRC] provided a report on the *Status of the Surface-Only Flux Algorithms*. He described the improvements made to the SW and LW surface flux model, and discussed the status of Total Solar Irradiance (TSI) measurements. Specifically, as Solar Radiation and Climate Experiment (SORCE) TSI data were not available on a regular basis from July 2013 through February 2014, a TSI composite was developed based upon observations from SORCE and the Royal Meteorological Institute of Belgium (RMIB) for the timeframe of CERES on Terra, Aqua, and Suomi NPP.

Seiji Kato [LaRC] presented the *Surface and Atmospheric Radiation Budget Working Group Update* and discussed the status of the development of Edition 4 Synoptic Radiative Fluxes and Clouds (SYN). Kato also discussed CERES Energy Balanced and Filled (EBAF)-surface tuning over the Arctic, focusing on the effects of surface skin and near-surface air temperatures. He concluded that tuning reduced the skin temperature over sea ice and brought the skin temperature into closer agreement with MODIS-derived skin temperature.

Dave Doelling [LaRC] presented the *Time Interpolation and Space Averaging* (TISA) Working Group report. He summarized the improvements the TISA team has made for delivery of Edition 4. He also discussed the intercalibrations between MODIS onboard Aqua and VIIRS onboard Suomi NPP, using simultaneous nadir overpass data based upon ray-matching methodology. Doelling also provided the SW and LW narrowband-to-broadband conversion strategies that will be used for the Edition 4 delivery.

Jonathan Gleason [LaRC] presented the *CERES Data Management Team and Atmospheric Science Data Center (ASDC) Status* report. He gave an overview of CERES AuTomAted job Loading sYSTem (CATALYST) and progress made since the last meeting. He then discussed the plan to release CATALYST 2.0 based upon the lessons learned from CATALYST 1.0. Gleason presented the timetables for planned CERES software deliveries, and described the ASDC, CERES, and Big Earth Data Initiative and the implementation of digital object identifiers for all EOS datasets.

Invited Science Presentations

The workshop had four invited presentations. The invited speakers addressed Earth's energy budget from different perspectives, and highlighted the importance of obtaining highly accurate Earth radiative flux measurements.

Benoit Meyssignac [Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS), CNES] discussed *Sea-level Rise and Earth's Energy Imbalance*, describing the use of highly accurate satellite altimetry for sea-level measurements and sea-level trends using data from the past 20 years. Meyssignac noted that the global mean sea level is rising quickly, caused by upper-ocean thermal expansion and land-ice melting. He then used satellite altimetry, Gravity Recovery and Climate Experiment (GRACE[6]), and Argo[7] data to assess how closely state-of-the-art measurements can be used to "close" the global sea level budget. He concluded that from these measurements the Earth's energy imbalance is estimated to be 0.7 ± 0.5 W/m^{-2}.

Aiko Voigt [Columbia University] discussed *Hemispheric (A)symmetries and Tropical Climate.* He described hemispheric symmetry in all-sky reflected SW flux using CERES observations, which is surprising given the known large asymmetry in clear-sky SW flux. He then discussed the tropical compensation mechanism in which the intertropical convergence zone (ITCZ) and tropical rainfall shifts toward the dark surface hemisphere, noting that models with too-little reflection from clouds over the Southern Ocean tend to have *double ITCZs*[8] in the Eastern Pacific.

Graeme Stephens [NASA/Jet Propulsion Laboratory] described *The Earth's Energy Balance and the Climate System,* focusing on the challenge of closing Earth's energy balance and the two analytical pathways that have been taken. The energy imbalance and ocean heat content were also addressed using CERES and Argo data. The heat is mostly being absorbed in the Southern Ocean and the enhanced heat uptake by the Southern Hemisphere implies a transport across the equator to the Northern Hemisphere. The transport of heat across the equator is fundamental to understanding the hydrological cycle and how it changes over time.

[6] NASA's twin GRACE satellites accurately map variations in Earth's gravity field.
[7] Argo is a broad-scale global array of 3750 temperature/salinity profiling floats.
[8] A double ITCZ is formed when a convergence zone forms north of the equator and another convergence zone forms south of the equator. When this occurs, a narrow ridge of high pressure forms between the two convergence zones, one of which is usually stronger than the other.

Richard Allan [University of Reading] presented *From the West African Monsoon up to Planetary Climate Changes: Synergy Between Earth Radiation Budget Measurements.* He discussed the synergetic use of CERES, GERB, and other satellite datasets in evaluating cloud processes, the diurnal cycle of convection, and TOA and surface radiation biases in climate models. Allan also described the methodology for reconstructing the global radiative fluxes prior to 2000 and combining Earth radiation budget data and ocean heat content measurements to better understand at what rate the Earth's energy budget is changing.

Joint Session on Synergy Between the Missions

This session included presentations on calibration consistency among different Earth radiation measurement platforms and some science results that take advantage of the synergy between CERES, ScaRaB, and GERB. Some of the results presented during this session were obtained during a special intercalibration campaign conducted in 2012 to understand the calibration consistency between CERES and ScaRaB.

Wenying Su [LaRC] presented the *Radiance/Flux Comparisons for CERES Aqua/Suomi-NPP and CERES Terra/ScaRaB.* She first provided radiance comparisons between matched Aqua and Suomi NPP footprints, and explained that SW radiance from Suomi NPP is higher than that from Aqua by about 1.5%, and the LW radiance from Suomi NPP is lower than Aqua by about 1-1.5%. She then presented a comparison between ScaRaB and CERES Terra using data collected during a special CERES and ScaRaB intercomparison campaign, conducted between April and June 2012. CERES radiances were averaged over the ScaRaB footprint by using the ScaRaB point spread function. Su reported that the SW radiance from ScaRaB is higher than that from CERES onboard Terra by about 2%—see **Figure 1**—and

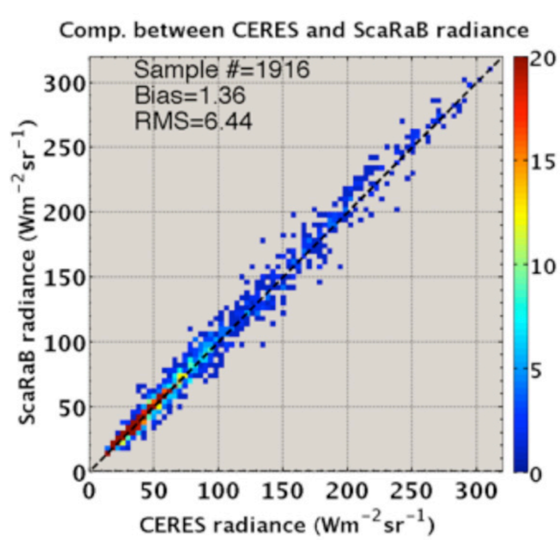

Figure 1. Shortwave radiance comparison between ScaRaB and CERES. **Image credit:** Wenying Su

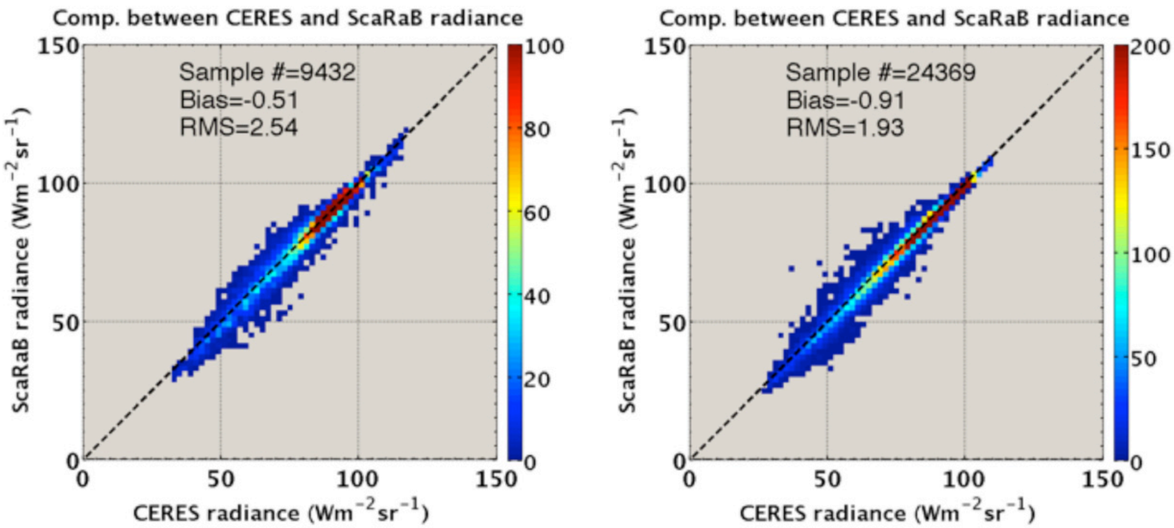

Figure 2. Longwave radiance comparison between ScaRaB and CERES during daytime [*left*] and nighttime [*right*]. **Image credit:** Wenying Su

the LW radiance from ScaRaB agreed with that from CERES onboard Terra to within 1%—see **Figure 2**.

David Doelling presented *CERES/GERB/ScaRaB Comparisons*, which included gridded monthly mean flux comparisons—first between ScaRaB and CERES, then between GERB and CERES. He found that the LW flux bias is between 0.5% and 1%, between ScaRaB and CERES; however, the SW flux bias is much larger (~6%). The LW flux bias is between 1.5% and 2% between GERB and CERES, and the SW flux bias is about 8% when compared to GERB-2 and 0% when compared to GERB-1. (Comparisons such as these help the team better understand the differences in instrument calibrations and algorithm implementations for different Earth radiation instruments.)

Jacqui Russell [Imperial College] presented *A Time Series of GERB-CERES Comparison,* wherein she described the method of relative calibration between CERES and GERB SW measurements over the lifetime of the GERB mission. The radiance agreement ranges from 0.4% to 1.6%, depending on the CERES instrument used. The radiance agreement over different surface types was also investigated.

Remy Roca and **Dominique Bouniol** [Both at CNRS] presented results using data from ScaRaB, CERES, MODIS, and CloudSat to study mesoscale convective systems (MCS). **Roca** presented *MCS Life Cycle TOA Flux from ScaRaB*, where he used an object-oriented tracking algorithm coupled to a classification/composite scheme to document the radiation properties of the MCS over the entire tropical belt. **Bouniol** presented *Mesoscale Convective System Life Cycle: TOA/BOA Fluxes and Profiles from CERES/MODIS/CloudSat.* She examined fluxes and flux profiles in three parts of an MCS—convective, stratiform, and nonprecipitating anvils, for two geographical regions: West African Monsoon region and the adjacent Atlantic Ocean region. She found that the MCS life cycles are very different between the two regions, both in their microphysical properties and radiative profiles.

Contributed Science Presentations

A variety of topics were covered during the contributed science presentations, which took place October 8-10. These presentations included such topics as aerosol and cloud radiative effects, climate model assessments, validation efforts, and discussions about algorithm improvements. **Tables 3-5** list the contributed science presentations by day.

Table 3: Contributed science presentations on October 8.

Speaker [Affiliation]	**Topic**
Helene Chepfer [LMD]	Observations of cloud change due to climate warming
Bill Smith [LaRC]	Overview of Arctic Radiation-IceBridge Sea and Ice Experiment (ARISE)
Baike Xi [University of North Dakota]	Validation of CERES Edition 4 Arctic cloud properties using Atmospheric Radiation Measurement results

Table 4: Contributed science presentations on October 9.

Speaker [Affiliation]	**Topic**
Helen Brindley [Imperial College]	The daytime cycle in dust aerosol direct radiative effects observed in the central Sahara during June 2011
Françoise Guichard [Centre National de Recherches Météorologiques - Groupe d'étude de l'Atmosphère Météorologique (CNRM-GAME)]	Processes shaping the surface radiation budget in West Africa: observations versus Coupled Model Intercomparison Project Phase 5 (CMIP5) models
Olivier Geoffroy [CNRM-GAME]	Clouds and aerosols radiative effects over West Africa, seasonal and meridional patterns
Mamadou Drame [CNRM-GAME]	The importance of aerosol composition for estimating incoming solar radiation: Focus on the Western African stations of Dakar and Niamey during the dry season
Geneviève Sèze [LMD]	Diurnal cycle of clouds from geostationary observations
Veerappan Sathiyamoorthy [ISRO]	Validation of ScaRaB/Megha-Tropiques flux data from ISRO and its use in understanding monsoon clouds
Steven Dewitte [RMIB]	The RMIB space odyssey from Total Solar Irradiance to the Sun-Earth IMBAlance (SIMBA)

Table 5: Contributed science presentations on October 10.

Speaker [Affiliation]	**Topic**
Helene Brindley [Imperial College]	Interannual variability in spectrally resolved TOA radiation diagnosed from five years of Infrared Atmospheric Sounding Interferometer (IASI) observations
Joseph Corbett [SSAI]	Comparing the relative stability of CERES, MODIS, and Multi-angle Imaging SpectroRadiometer (MISR) radiances
Nicolas Clerbaux [RMIB]	The Satellite Application Facility on Climate Monitoring (CM SAF) TOA and surface radiation products and datasets
Norman Loeb [LaRC]	Exploration of the hemispheric asymmetry in the surface energy budget using CERES and reanalysis data
Remy Roca [CNRS]	Long-term monitoring of ScaRaB using a geophysical approach
Bijoy Thampi [SSAI]	Scene classification from CERES radiances using the Random Forests method
Zachary Eitzen [SSAI]	Development of the CERES Flux-by-cloud type simulator
Florian Tornow [Freie University]	On the use of simulated photon paths to co-register TOA radiances in EarthCARE radiative closure experiments

Summary

The joint CERES/ScaRaB/GERB meeting described here was highly successful. It provided an opportunity for the three Earth radiation measurement teams to discuss and receive feedback on the status of each project, the instruments, and the data products. A central focus of the meeting was on results from a special intercalibration campaign conducted in 2012. The teams identified outstanding questions and challenges in Earth radiation budget observation and research. The teams discussed possible future intercalibration campaigns that can help address remaining observational challenges. The invited and contributed science sessions were highly stimulating, and demonstrated how the science community is using data products from these three projects to address a wide range of research problems that involve Earth's energy budget.

The next CERES Science Team meeting will be held May 5-7, 2015, at LaRC in Hampton, VA.

NASA Sounder Science Team Meeting

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The NASA Sounder Science Team Meeting (STM) was held from September 30 to October 2, 2014, at the Greenbelt Marriott Hotel in Greenbelt, MD. The Atmospheric Infrared Sounder (AIRS) Project at NASA/Jet Propulsion Laboratory (JPL) hosted the meeting. This report highlights some of the key results presented at the meeting; the complete list of presentations can be viewed in the document found at *airs.jpl.nasa.gov/system/internal_resources/details/original/132_stm-agenda-201409.pdf*. Most of the presentations' contents are posted at *airs.jpl.nasa.gov/events/6?s=true*.

Overview

The general theme of the meeting was scientific results using atmospheric sounder observations, but there were also presentations that focused on instrument operations, algorithm development, and data processing and archiving. With several sounding instruments currently on various orbiting platforms, the presenters showed results from a broad range of scientific and technical disciplines. The meeting began with an opening plenary session, followed by a series of technical sessions throughout the three days that included:

- Operational Data Products Systems;
- Atmospheric Sounding for Climate;
- Applications Using Sounding Data;
- Weather Forecast Improvement and Data Assimilation;
- Atmospheric Composition and Aerosols;
- Atmospheric Thermodynamics;
- Algorithm Improvements and Research Products;
- Instrument Calibration; and
- Future Atmospheric Sounding Measurement Ideas.

Highlights from the Technical Sessions

Lazaros Oreopoulos [NASA's Goddard Space Flight Center (GSFC)] described how he used Moderate Resolution Imaging Spectroradiometer (MODIS) cloud-top pressure and optical depth observations to characterize nine distinct atmospheric cloud regimes. The regimes were defined globally, but occur in preferred geographic locations and exhibit consistent differences in large-scale vertical velocity, cloud radiative forcing at the surface, and precipitation. Using data from the AIRS on Aqua and the Modern-Era Retrospective Analysis for Research and Applications (MERRA), he also showed that the regimes have distinct temperature and relative humidity properties. Preliminary analysis showed that the regimes also have distinct cloud microphysical properties as observed by MODIS and AIRS on Aqua. Oreopoulos noted that the resulting physically consistent picture from multiple instruments and reanalyses provides insights into processes controlling Earth's energy balance.

Jie Gong [GSFC] demonstrated how concentric gravity waves—detectable in AIRS 4-µm radiances in the stratosphere—are forced by storms in the troposphere. Because of their large amplitude, these waves are important in carrying momentum from the troposphere to upper atmospheric levels, and can propagate to altitudes as high as the ionosphere. Based on morphology, Gong developed a climatology of concentric gravity waves in AIRS data, and showed maxima in the tropics and over Southern Hemisphere storm tracks. She also showed that they propagate into the prevailing winds. A comparison of the waves measured by AIRS with similar structures in the European Centre for Medium-range Weather Forecasting (ECMWF) reanalysis showed the reanalysis waves have smaller amplitudes, but occur more frequently.

Juying Warner [University of Maryland, College Park (UMd)] described how atmospheric ammonia is increasing as a result of increased livestock husbandry—with the caveat that the satellite record of ammonia is limited. Using twelve years of AIRS retrievals, she presented global maps of ammonia distribution and showed upward ammonia trends over highly populated regions in Europe, North America, and Asia. Tropical and high-latitude regions also showed higher ammonia amounts—attributable to biomass burning. She also showed a time series of ammonia levels over populated regions, and noted that increasing ammonia was not correlated with carbon monoxide (generally produced in wildfires), indicating the likely source of the ammonia emissions is livestock. Ammonia trends over biomass burning regions were less apparent.

Linette Boisvert [GSFC] described the challenges of estimating Arctic oceanic surface heat and moisture fluxes using *in situ* and satellite observations. Her calculation requires observations of sea surface temperature, ice cover, and near-surface temperature, humidity, and wind speed. Despite the challenges in estimating them, moisture fluxes play a significant role in regional energy and moisture budgets. Boisvert also showed significant regional upward trends in sea surface temperatures and moisture fluxes into the atmosphere, and showed that these are collocated with regions of large downward trends in sea ice cover.

Patrick Boylan [National Center for Atmospheric Research] described the dropsonde correlative data source used in this study, which are released from balloons floating at constant pressure in the lower stratosphere. With balloons confined by the Antarctic polar vortex, most of the soundings were located over or near the Antarctic continent. He described near-surface temperature inversions—an important but little-studied characteristic of Antarctica—in both the sondes' data and in AIRS retrievals. Boylan showed that AIRS is able to identify temperature inversions approximately 80% of the time they are detected by sondes, but the AIRS retrievals tend to underestimate near-surface air temperatures and the associated strengths of inversions.

George Aumann [JPL] compared nadir radiances, near 900 cm^{-1}, simultaneously observed by the AIRS on Aqua and the Infrared Atmospheric Sounding Instrument (IASI) spectrometers flying on the European METOP series of satellites. He showed small differences between the measurements almost everywhere under most conditions. However, systematic mean differences of ~0.35 K in brightness temperature were found for tropical land conditions, and ~1 K for the coldest 10% of scenes. Aumann attributed these to differences in the two instruments' responses to cloudy scenes, which are typically the coldest tropical scenes.

Antonia Gambacorta [National Oceanic and Atmospheric Administration's (NOAA), Center for Satellite Applications and Research (STAR)] described a theoretical study to understand the effects of inhomogeneous scenes on geophysical quantities retrieved from the associated radiances. Such a study has relevance to, e.g., **George Aumann's** presentation (see previous paragraph), which quantified the effects of cloud inhomogeneity on observed radiances. Gambacorta showed that the effects of inhomogeneities within single scenes are not the major source of uncertainties in retrievals from interferometers. Instead, retrieval errors are dominated by differences between adjacent scenes. Current retrieval algorithms use several adjacent infrared fields of view (usually four or six) to obtain a single retrieval, and assume constant values between fields of view for all quantities except clouds. Gambacorta showed that interscene differences—notably in surface properties and water vapor—could contribute errors significantly larger than those contributed by inhomogeneities within individual infrared fields of view.

Closing Discussion and Summary

Three high-resolution infrared sounders and several microwave sounders have been launched since the inception of the AIRS/Advanced Microwave Sounding Unit (AMSU) record in mid-2002. Several more sounders are scheduled for launch in the coming years. The presentations given at the STM showed that these instruments are now playing a central role in improving weather forecasting, climate modeling, and knowledge of atmospheric trace gases. Future NASA sounder meetings will highlight the progress made with these instruments.

The next Sounder Science Team meeting is planned for April 2015 in Pasadena, CA. ■

Acronyms used in the Editorial and Article Titles

A-Train	Afternoon Constellation	ISS-RapidSCAT	International Space Station Rapid Scatterometer
AO	Announcement of Opportunity	MISR	Multiangle Imaging Spectroradiometer
CALIPSO	Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations	MLS	Microwave Limb Sounder
CERES	Clouds and the Earth's Radiative Energy System	MODIS	Moderate Resolution Imaging Spectroradiometer
EarthCARE	Earth Clouds, Aerosols and Radiation Explorer	NOAA	National Oceanic and Atmospheric Administration
EOS	Earth Observing System	OCO-2	Orbiting Carbon Observatory-2
ESA	European Space Agency	PI	Principal Investigator
ESSP	Earth System Science Pathfinder	ScaRaB	Scanner for Radiation Budget
GERB	Geostationary Earth Radiation Budget	SMAP	Soil Moisture Active Passive
GOFC–GOLD	Global Observation of Forest and Land Cover Dynamics	SORCE	Solar Radiation and Climate Experiment
GPM	Global Precipitation Measurement	TSIS	Total and Spectral Solar Irradiance Sensor

Congratulations *William T. Pecora Award* Winners!

The Earth Observer is pleased to recognize the entire **Landsat 8 Team** that built and now operates Landsat 8 (the latest in the Landsat series of satellites), and **Christopher Justice** [University of Maryland, College Park—*Program Scientist for the NASA Land Cover Land Use Change Program*] for receiving the 2014 *William T. Pecora* Team Award and Individual Award, respectively.

The William T. Pecora Award was established in 1974 to honor the memory of William T. Pecora, former Director of the U.S. Geological Survey (USGS) and Undersecretary of the Department of Interior (DoI). Pecora was a motivating force behind the establishment of a program for civil remote sensing of Earth from space. His early vision and support helped establish what we know today as the Landsat satellite program, which created a continuous record of Earth's land areas that has now spanned a period of more than 40 years.

The award is sponsored by DoI's USGS and NASA, and presented annually to individuals and/or groups that make outstanding contributions toward understanding Earth by means of remote sensing. This year's award was presented on November 18, 2014, in Denver, CO, at the 19th William T. Pecora Memorial Remote Sensing Symposium.

For more information about the award including definitions of and criteria for team and group awards, eligibility, nomination process, etc., visit *remotesensing.usgs.gov/pecora.php*.

Team Award

Landsat 8, which launched as the Landsat Data Continuity Mission (LDCM) in February 2013, provides frequent, global, medium-resolution data for science and applications. Landsat 8 extends the unprecedented Landsat data record which now covers more than four decades.

The **Landsat 8 Team** is a partnership between USGS and NASA—with strong contributions from industry and the academic community. The Landsat 8 Project Office at NASA's Goddard Space Flight Center (GSFC) oversaw development and launch of the satellite. The USGS Earth Resources Observation and Science Center in Sioux Falls, SD, managed ground system development and assumed operation of the mission following in-orbit commissioning.

Landsat 8's Thermal Infrared Sensor (TIRS) was built at GSFC. Ball Aerospace & Technology Corporation was responsible for the Operational Land Imager (OLI). Orbital Sciences Corporation built the spacecraft, and United Launch Alliance provided the Atlas 2 launch vehicle. The Landsat Science Team of university and government scientists provided scientific and technical input to a wide range of mission activities.

The Landsat 8 Team met the challenge of continuing and advancing the Landsat legacy of observations. The OLI sensor on Landsat 8 is a substantial technical advancement over the series of Thematic Mapper sensors flown since 1982 on Landsats 4, 5, and 7. In addition, the TIRS instrument utilizes a two-band thermal infrared sensor to more effectively address atmospheric contamination in the thermal infrared spectrum. Mission performance has exceeded expectations, providing more imagery, higher-quality measurements, and new capabilities over previous missions.

Individual Award

Christopher Justice has made numerous scientific contributions to the study of land-use and land-cover change and the detection and analysis of wildfires, expanding the use of Earth-observing data from NASA's Moderate-Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) instruments. An innovator in the use of global daily polar-orbiter satellite data for mapping and monitoring land cover, Justice provided the vision that led to the first global 1-km- (~0.6-mi-) resolution Advanced Very High Resolution Radiometer (AVHRR) dataset. He leads long-term monitoring of the Congo Basin using Landsat data—an effort that provides invaluable information on the state of the forests of central Africa.

Justice is perhaps best known for his research on wildfires. First using AVHRR data and now from MODIS and VIIRS, he successfully developed algorithms for fire detection and burned-area estimation. He spearheaded the development of a rapid-response system that reveals the location of fires shortly after images are obtained. This system has provided significant practical benefits in many parts of the world, and is regularly used in strategic deployment of fire-fighting assets.

Justice now leads agricultural monitoring efforts. With colleagues from NASA and the U.S. Department of Agriculture, he leads the development of a system for forecasting agricultural production based primarily on MODIS data. He is working on transitioning the system to use VIIRS data to ensure longer-term continuity.

The Earth Observer congratulates Justice and the entire Landsat 8 Team for receiving such prestigious awards!

NASA's Spaceborne Carbon Counter Maps New Details

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

The first global maps of atmospheric carbon dioxide (CO_2) from NASA's new Orbiting Carbon Observatory-2 (OCO-2[1]) mission demonstrate its performance and promise, showing elevated CO_2 concentrations across the Southern Hemisphere from springtime biomass burning.

At a media briefing at the American Geophysical Union (AGU) Fall Meeting held December 14-18, 2014 in San Francisco, CA, scientists from NASA/Jet Propulsion Laboratory (JPL); Colorado State University (CSU); and the California Institute of Technology (Caltech) presented the maps of CO_2 and a related phenomenon known as solar-induced chlorophyll fluorescence and discussed their potential implications—see **Figures 1-2**. The maps show elevated CO_2 concentrations and solar-induced chlorophyll fluorescence in the atmosphere above northern Australia, southern Africa, and eastern Brazil.

"Preliminary analysis shows these signals are largely driven by the seasonal burning of savannas and forests," said **Annmarie Eldering** [JPL—*OCO-2 Deputy Project Scientist*]. The team is comparing these measurements with data from other satellites to clarify how much of the observed concentration is likely due to biomass burning.

[1] To learn about the OCO-2 mission, read "Orbiting Carbon Observatory-2: Observing CO_2 from Space" in the July-August issue of *The Earth Observer* [**Volume 26, Issue 4,** pp. 4-12].

The period represented by the maps is spring in the Southern Hemisphere, when agricultural fires and land clearing are widespread. The impact of these activities on global CO_2 has not been well quantified. As OCO-2 acquires more data, Eldering said, its Southern Hemisphere measurements could lead to an improved understanding of the relative importance in these regions of photosynthesis in tropical plants, which removes CO_2 from the atmosphere, and biomass burning, which releases CO_2 to the atmosphere.

The early OCO-2 data hint at some potential surprises to come. "The agreement between OCO-2 and models based on existing CO_2 data is remarkably good, but there are some interesting differences," said **Christopher O'Dell** [CSU—*Assistant Professor of Atmospheric Sciences*]. "Some of the differences may be due to systematic errors in our measurements, and we are currently in the process of nailing these down. But some of the differences are likely due to gaps in our current knowledge of carbon sources in certain regions—gaps that OCO-2 will help fill in."

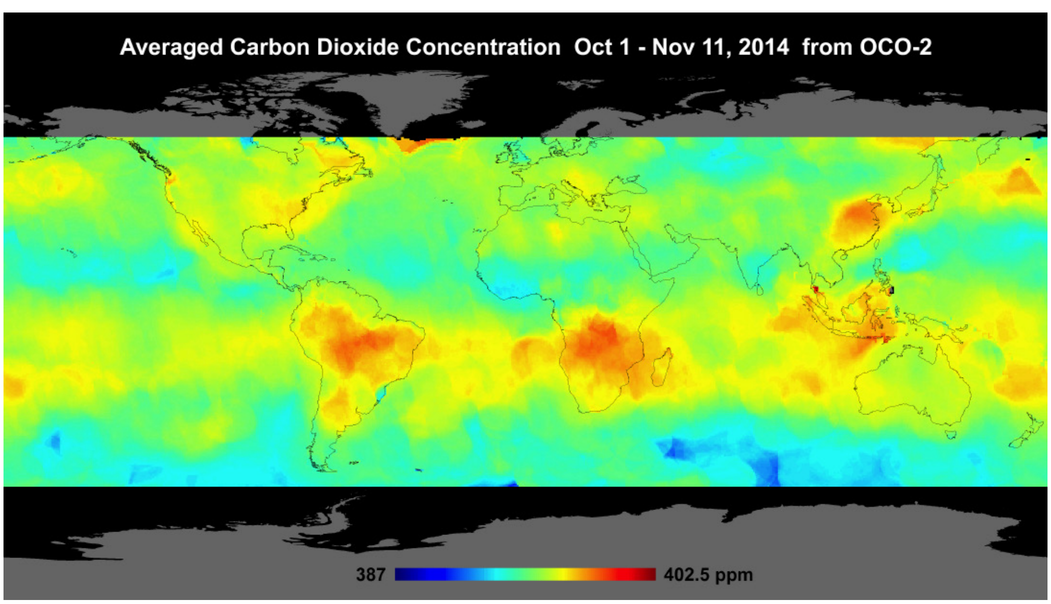

Figure 1. This map shows global atmospheric CO_2 concentrations from October 1 through November 11, 2014, as recorded by NASA's OCO-2 spacecraft. The highest concentrations of CO_2 are above northern Australia, over southern Africa, and in eastern Brazil. **Image credit:** NASA/JPL-Caltech

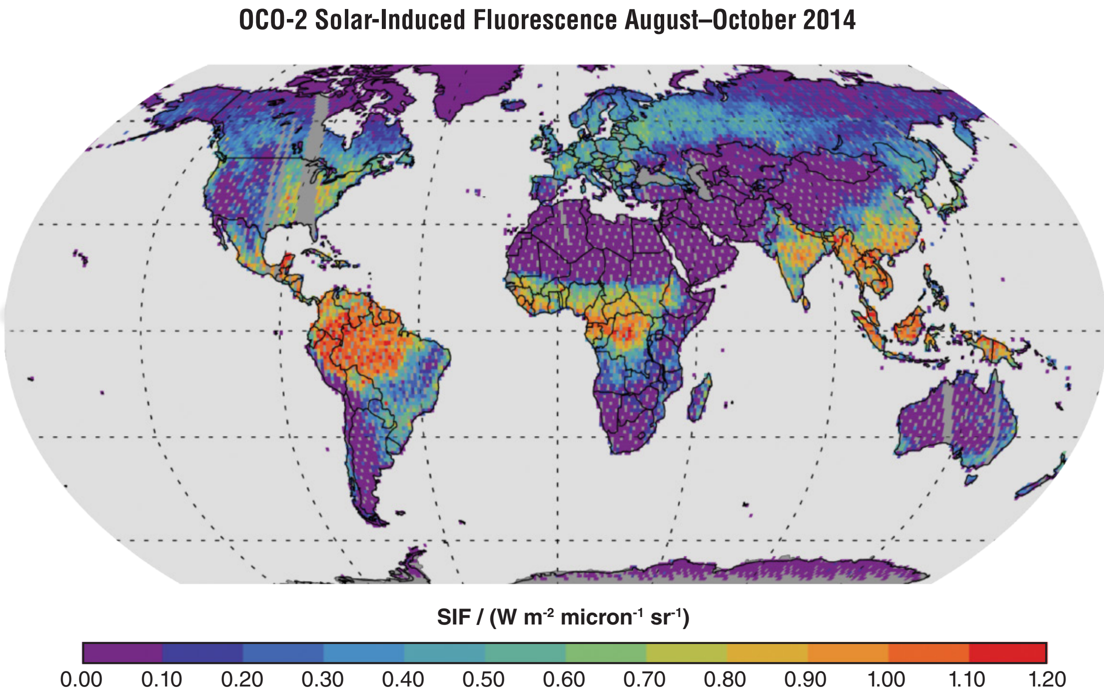

Figure 2. This map shows *solar-induced fluorescence*, a plant process that occurs during photosynthesis, from August 1 through October 31, 2014, as measured by NASA's OCO-2 spacecraft. This period is springtime in the Southern Hemisphere and fall in the Northern Hemisphere. **Image credit:** NASA/JPL-Caltech

Elevated CO_2 could have a natural cause—e.g., a drought that reduced plant growth—or a human cause, but there has been no effective means to distinguish between these sources—until now. Elevated CO_2 over a region could have a natural cause—for example, a drought that reduces plant growth—or a human cause. At the AGU media briefing, **Christian Frankenberg** [JPL] introduced a map using a new type of data analysis from OCO-2 that can help scientists distinguish the gas's natural sources. Through photosynthesis, plants remove CO_2 from the air and use sunlight to synthesize the carbon into food. Plants end up re-emitting about 1% of the sunlight at longer wavelengths. Using one of OCO-2's three spectrometer instruments, scientists can measure the re-emitted light, known as *solar-induced chlorophyll fluorescence* (SIF). This measurement complements OCO-2's CO_2 data with information on when and where plants are drawing carbon from the atmosphere.

"Where OCO-2 really excels is the sheer amount of data being collected within a day—about one million measurements across a narrow swath," Frankenberg said. "For fluorescence, this enables us, for the first time, to look at features on the 5- to 10-km (~3-6 mi) scale on a daily basis." SIF can be measured even through moderately thick clouds, so it will be especially useful in understanding regions like the Amazon where cloud cover thwarts most spaceborne observations.

The changes in atmospheric CO_2 that OCO-2 seeks to measure are so small that the mission must take unusual precautions to ensure the instrument is free of errors. For that reason, the spacecraft was designed so that it can make an extra maneuver: In addition to gathering a straight line of data like a lawnmower swath, the instrument can point at a single target on the ground for a total of seven minutes as it passes overhead. This requires the spacecraft to turn sideways and make a half cartwheel to keep the target in its sights.

The targets OCO-2 uses are stations in the Total Carbon Column Observing Network (TCCON[2]), a collaborative effort of multiple international institutions. TCCON has been collecting CO_2 data for about five years, and its measurements are fully calibrated and extremely accurate. At the same time that OCO-2 targets a TCCON site, a ground-based instrument at the site makes the same measurement. The extent to which the two measurements agree indicates how well calibrated the OCO-2 sensors are.

Additional maps released during AGU showed the results of these targeting maneuvers over two TCCON sites in California and one in Australia. "Early results are very promising," said **Paul Wennberg** [Caltech—*TCCON Chair*]. "Over the next few months, the team will refine the OCO-2 data, and we anticipate that these comparisons will continue to improve."

For additional information about OCO-2, visit *oco2.jpl.nasa.gov*. ■

2 To learn more about TCCON, read "Integrating Carbon from the Ground Up: TCCON Turns Ten" in the July–August 2014 issue of *The Earth Observer* [**Volume 26**, **Issue 4**, pp. 13-17].

NASA Satellites Measure Increase of Sun's Energy Absorbed in the Arctic

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

NASA satellite instruments have observed a marked increase in solar radiation absorbed in the Arctic since the year 2000—a trend that aligns with the steady decrease in Arctic sea ice during the same period.

While sea ice is mostly white and reflects the sun's rays, ocean water is dark and absorbs the sun's energy at a higher rate. A decline in the region's *albedo*—its reflectivity, in effect—has been a key concern among scientists since the summer Arctic sea ice cover began shrinking in recent decades. As more of the sun's energy is absorbed by the climate system, it enhances ongoing warming in the region, which is more pronounced than anywhere else on the planet.

Since the year 2000, the rate of absorbed solar radiation in the Arctic in June, July, and August has increased by 5%, said **Norman Loeb** [NASA's Langley Research Center]. These measurements come from NASA's Clouds and the Earth's Radiant Energy System (CERES) instruments, which fly on multiple satellites—see **Figure**.

While a 5% increase may not seem like much, consider that the rate globally has remained essentially flat during that same time. No other region on Earth shows a trend of potential long-term change. When averaged over the entire Arctic Ocean, the increase in the rate of absorbed solar radiation is about 10 W/m^2. This is equivalent to an extra 10-W light bulb shining continuously over every 10.76 ft^2 (~1 m^2) of Arctic Ocean for the entire summer.

continued on page 47

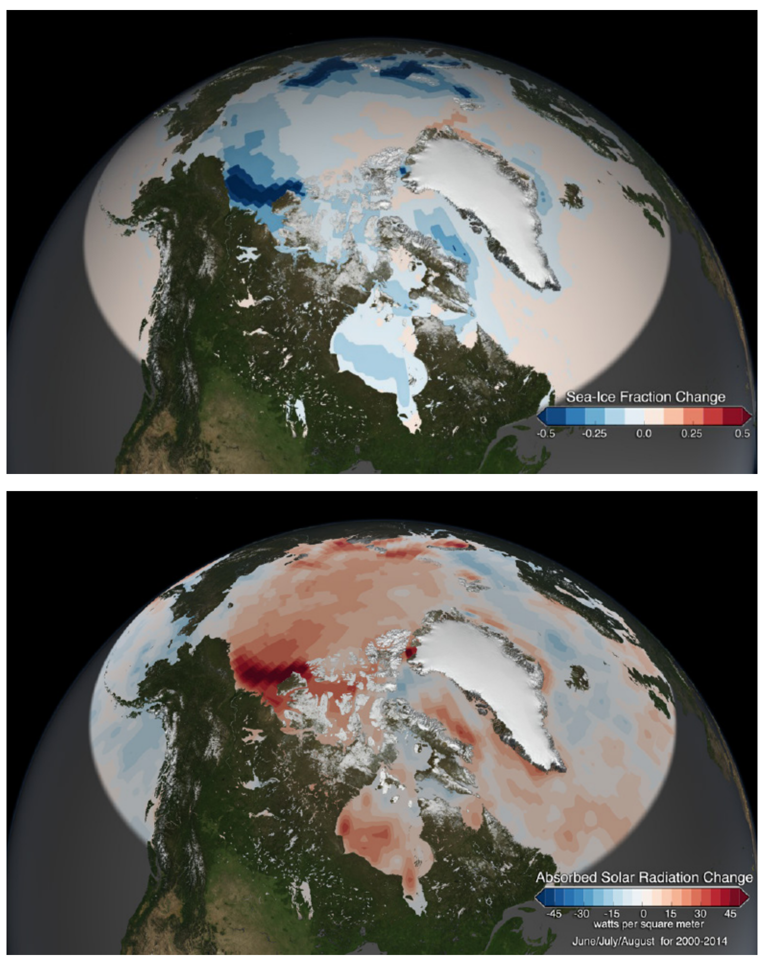

Figure. These images show a decrease in sea ice [*top*] and a corresponding increase in absorption of solar energy [*bottom*] in the Arctic Ocean during June, July, and August between 2000 and 2014, as derived from CERES data. The increase in absorption of solar energy arises from melting of reflective sea ice and consequent exposure of darker ocean waters. **Image credit:** NASA's Scientific Visualization Studio/Lori Perkins

NASA Analysis: 11 Trillion Gallons to Replenish California Drought Losses

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EDITOR'S NOTE: This article is taken from *nasa.gov*. While it has been modified slightly to match the style used in *The Earth Observer*, the intent is to reprint it with its original form largely intact.

It will take about 11 trillion gallons of water (~42 km^3)—around 1.5 times the maximum volume of the largest U.S. reservoir—to recover from California's continuing drought, according to a new analysis of NASA satellite data.

The finding was part of a sobering update on the state's drought made possible by space and airborne measurements and presented by NASA scientists on December 16, 2014, at the American Geophysical Union (AGU) Fall Meeting held in San Francisco, CA. Such data are giving scientists an unprecedented ability to identify key features of droughts—data that can be used to inform water management decisions.

A team of scientists led by **Jay Famiglietti** [NASA/Jet Propulsion Laboratory (JPL)] used data from NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites to develop the first-ever calculation of this kind—determining the volume of water required to end an episode of drought.

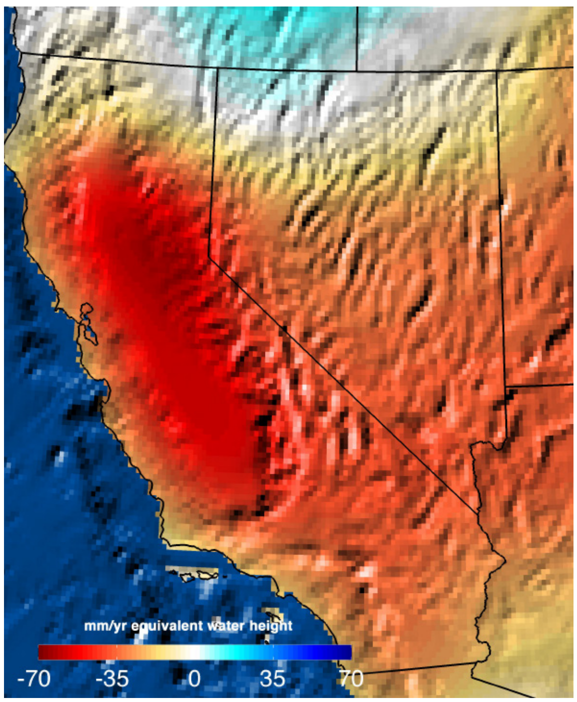


Figure. Data from NASA's GRACE satellites reveals the impact that California's multiyear drought is having on water resources across the state. This map shows the trend in water storage between September 2011 and September 2014. **Image credit:** NASA/Jet Propulsion Laboratory

Earlier this year, at the peak of California's current three-year drought, the team found that water storage in the state's Sacramento and San Joaquin river basins was 11 trillion gallons below normal seasonal levels. Data collected since the launch of GRACE in 2002 shows this deficit has increased steadily.

"Spaceborne and airborne measurements of Earth's changing shape, surface height, and gravity field now allow us to measure and analyze key features of droughts better than ever before, including determining precisely when they begin and end and what their magnitude is at any moment in time," Famiglietti said. "That's an incredible advance and something that would be impossible using only ground-based observations."

GRACE data reveal that, since 2011, the Sacramento and San Joaquin river basins decreased in volume by four trillion gallons of water each year (15 km^3)—see **Figure**. That's more water than California's 38 million residents use each year for domestic and municipal purposes. About two-thirds of the loss is due to depletion of groundwater beneath California's Central Valley.

In related results, data from NASA's Airborne Snow Observatory, collected in early 2014, indicate that snowpack in California's Sierra Nevada range was only half of previous estimates. The observatory is providing the first-ever, high-resolution observations of snow water volume in the Tuolumne River, Merced, Kings, and Lakes basins of the Sierra Nevada, and the Uncompahgre watershed in the Upper Colorado River Basin.

To develop these calculations, the observatory measures how much water is in the snowpack and how much sunlight the snow absorbs, which influences how fast the snow melts. These data enable accurate estimates of how much water will flow out of a basin when the snow melts, which helps guide decision about reservoir filling and water allocation.

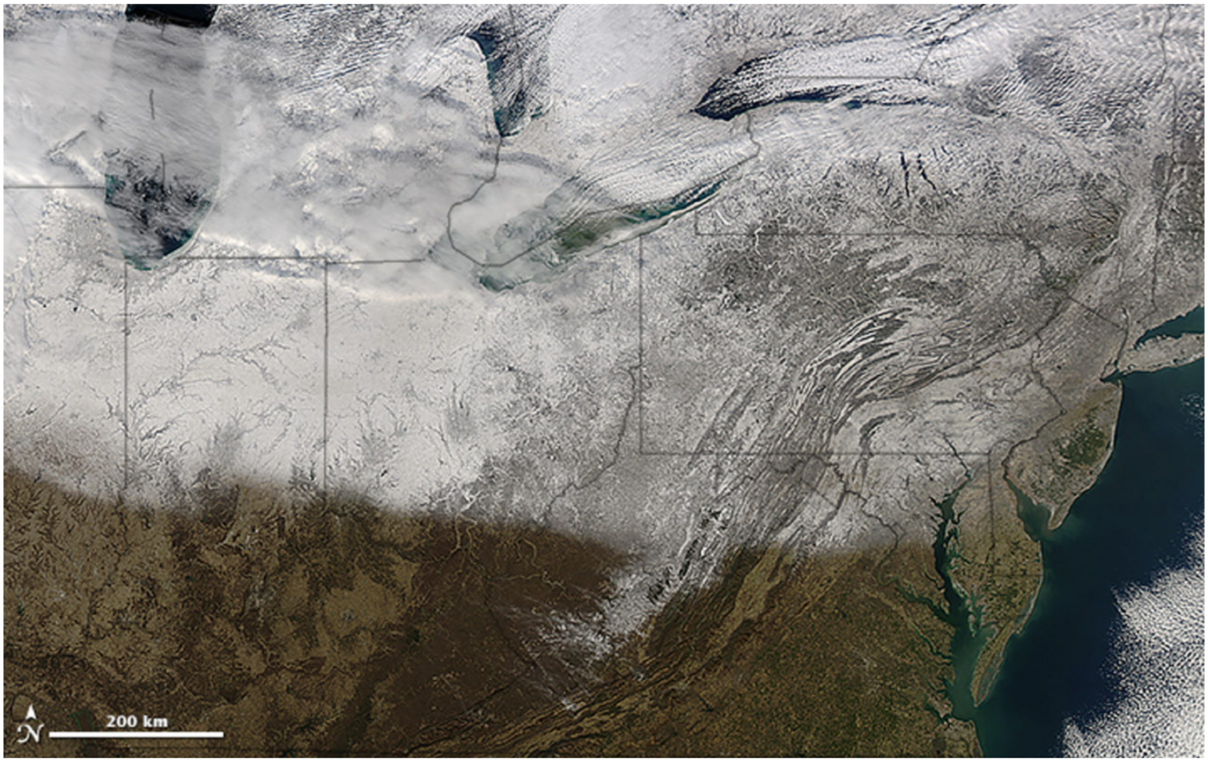
"The 2014 snowpack was one of the three lowest on record and the worst since 1977, when California's population was half what it is now," said **Tom Painter** [JPL—*Airborne Snow Observatory Principal Investigator*]. "Besides resulting in less snow water, the dramatic reduction in snow extent contributes to

continued on page 47

Snow in the Northeastern U.S.

Kathryn Hansen, NASA's Goddard Space Flight Center, kathryn.h.hansen@nasa.gov

Winter storms brought snow and ice to a large portion of the U.S. Midwest and Northeast. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite acquired the top image on January 10, 2015. NASA's Aqua satellite acquired the bottom image on January 13, 2015. The offshore clouds over the Atlantic formed as a strong flow of cold air moved over the warmer waters of the Atlantic Ocean. **Image credit:** NASA LANCE/EOSDIS Rapid Response



Acquired January 10, 2015

Acquired January 13, 2015

NASA Satellites Measure Increase of Sun's Energy Absorbed in the Arctic

continued from page 44

Regionally, the increase is even greater, Loeb said. Areas such as the Beaufort Sea, which has experienced some of the most pronounced decreases in sea-ice coverage, show a 50 W/m^2 increase in the rate of absorbed solar radiation. "Advances in our understanding of Arctic climate change and the underlying processes that influence it will depend critically upon high quality observations like these from CERES," Loeb said.

As a region, the Arctic is showing more dramatic signs of climate change than any other spot on the planet. These include a warming of air temperatures at a rate two to three times greater than the rest of the planet and the loss of September sea ice extent at a rate of 13% per decade.

While these CERES measurements could ultimately become another of those signs of dramatic climate change, right now scientists say they have obtained the bare minimum of a data record needed to discern what is happening over the long term.

According to **Jennifer Kay** [Cooperative Institute for Research and Environmental Science, University of Colorado—*Atmospheric Scientist*], getting data beyond 15 years will allow scientists to better assess if recent trend falls outside the realm of natural variability. "We need long time series to detect climate change signals over the internal variability. For example, observed sea ice loss over the last 30 years cannot be explained by natural variability alone. Fifteen years is long, but climate is often defined as the average over 30 years—so we are only half-way there with the CERES observations."

Kay and colleagues have also analyzed satellite observations of Arctic clouds during this same 15-year period. Kay's research shows summer cloud amounts and vertical structure are not being affected by summer sea ice loss. While surprising, the observations show that the bright sea-ice surface is not automatically replaced by bright clouds. Indeed, sea ice loss—not clouds—explains the increases in absorbed solar radiation measured by CERES.

Increasing absorbed solar radiation is causing multiple changes in the sea ice cover, said **Walt Meier** [NASA's Goddard Space Flight Center]. Two of those changes include the timing of the beginning of the melt season each year and the loss of older, thicker sea ice.

The onset of the melt season in the high Arctic is now on average seven days earlier than it was in 1982, Meier said. Earlier melting can lead to increased solar radiation absorption. This is one step in a potential feedback cycle of warming leading to melting, melting leading to increased solar radiation absorption, and increased absorption leading to enhanced warming.

Since 2000, the Arctic has lost 1.4 million km^2 (~541,000 mi^2) of older ice that is more than 3 m (~10 ft) thick, which during winter has essentially been replaced by ice that is less than 2 m (~6.5 ft) thick, according to data provided by **Mark Tschudi** [University of Colorado]. Once again, **Walt Meier** said, this trend is a step in a feedback cycle. "Having younger and thus thinner ice during winter makes the system more vulnerable to ice loss during the summer melt season." ■

NASA Analysis: 11 Trillion Gallons to Replenish California Drought Losses

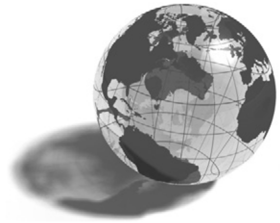
continued from page 45

warming our climate by allowing the ground to absorb more sunlight. This reduces soil moisture, which makes it harder to get water from the snow into reservoirs once it does start snowing again."

New drought maps show groundwater levels across the U.S. Southwest are in the lowest 2-10% since 1949. The maps, developed at NASA's Goddard Space Flight Center (GSFC), combine GRACE data with other satellite observations. "Integrating GRACE data with other satellite measurements provides a more holistic view of the impact of drought on water availability, including on groundwater resources, which are typically ignored in standard drought indices," said **Matt Rodell** [GSFC—*Chief of the Hydrological Sciences Laboratory*].

During the AGU meeting scientists cautioned that while the December rainstorms in California have been helpful in replenishing water resources, they aren't nearly enough to end the multi-year drought. "It takes years to get into a drought of this severity, and it will likely take many more big storms, and years, to crawl out of it," said Famiglietti.

For more information on GRACE, visit *www.nasa.gov/grace* and *www.csr.utexas.edu/grace*. ■



NASA Earth Science in the News

Patrick Lynch, NASA's Earth Science News Team, patrick.lynch@nasa.gov

Alaska Shows No Sign of Rising Methane Levels—For Now, November 14; *NatureWorldNews.com*. Climate scientists will be happy to hear that Alaska, despite experiencing large temperature increases in recent decades, is showing no signs of rising methane (CH_4) levels, at least for now. Previous studies had suggested that CH_4 from Alaskan soils was being released at unusually high rates, but a new study, based on data from NASA's Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE), suggests otherwise. "That's good news, because it means there isn't a large amount of methane coming out of the ground yet," said lead author **Rachel Chang** [Dalhousie University—*Assistant Professor of Physics and Atmospheric Science*]. However, that doesn't mean that that can't change in the future. CH_4 is the third most common greenhouse gas in the atmosphere, after water vapor and carbon dioxide (CO_2), and the most potent: It is 33 times more effective than CO_2 at trapping heat in the atmosphere and adding to greenhouse warming.

Mesmerizing NASA Visualization Shows Carbon Dioxide Concentrations in the Atmosphere, November 20; *Newsweek*. NASA has created a computer simulation that shows how levels of CO_2 fluctuate in the atmosphere on a yearly basis. The model is the first to show in such fine detail how CO_2 actually moves through the atmosphere. It is striking to see how most of the CO_2 originates from China, the U.S., and Europe, while locations in the Southern Hemisphere produce much less of the greenhouse gas. In some areas, CO_2 concentrations decline over the course of a day—caused by vegetation photosynthesizing and taking up the gas—and then go up again during the night when there is no sunlight. Overall levels decline in the summer as plants grow in the Northern Hemisphere. "While the presence of CO_2 has dramatic global consequences, it's fascinating to see how local emission sources and weather systems produce gradients of its concentration on a very regional scale," said **Bill Putman** [NASA's Goddard Space Flight Center (GSFC)—*Climate Scientist at the Global Modeling and Assimilation Office*].

Fastest-Melting Region of Antarctica Triples Rate in a Decade, December 2; *TIME*. According to a new analysis, the fastest-melting region of Antarctica is melting three times as fast as it was a decade ago—making it the largest-area contributor to the rise in sea level. The findings of the 21-year study by scientists at NASA/Jet Propulsion Laboratory (JPL) and the University of California, Irvine, offer the most precise estimates to date of just how fast glaciers in West Antarctica's Amundsen Sea Embayment are melting. Scientists determined the rate by taking several radar, laser, and satellite measurements of the glaciers' mass to measure changes over time; between 1992 and 2013, they lost an average of 91.5 billion U.S. tons per year. The findings will provide a greater understanding of glaciers and ice sheets, which the researchers labeled the biggest uncertainties in predicting future sea levels.

NASA Study: Vegetation Decline Seen in Wake of Drying Amazon, December 11; *United Press International*. As revealed by a newly concluded 13-year NASA study, vegetation in the Amazon is diminishing and is less green as precipitation totals have tapered. The research, showcased in the *Proceedings of the National Academy of Sciences*, features a new technique for analyzing vegetation health via satellite imagery. The technique involves the observation of a forest from low-Earth orbit, using data from Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on the Aqua and Terra satellites. While a separate study measured a 25% decline in rainfall across two-thirds of the Amazon between 2000 and 2012, the new NASA analysis calculated a corresponding 0.8% decline in greenness. The decline may seem small in comparison, but the nearly 1% de-greening effect can be seen across a swath of rainforest stretching 2.1 million mi^2 (~5.4 million km^2). "In other words, if greenness declines, this is an indication that less carbon will be removed from the atmosphere," lead study author **Thomas Hilker** [Oregon State University—*Remote Sensing Specialist*], who wrote the paper with several co-authors from GSFC. "The carbon storage of the Amazon basin is huge, and losing the ability to take up as much carbon could have global implications for climate change."

Why Greenland Could Lose More of Its Ice Sheet Than Predicted, December 16; *Christian Science Monitor*. Researchers say they have uncovered perennial freshwater lakes embedded within the upper layers of Greenland's ice sheet—previously unknown features that could play a role in the rate at which the sheet loses mass in a warming climate. The discovery, based in part on data collected during Operation IceBridge flights, comes as glaciologists are still trying to digest news from a year ago that the southeastern section of the ice sheet hosts a year-round aquifer of liquid water. The aquifer covers some 27,000 mi^2 (~70,000 km^2) and ranges from approximately 16 to 165 ft (5 to 50 m) thick, researchers have estimated. Since then, researchers have found other aquifers. The perennial lakes and aquifers are acting as a kind of internal thermometer, signaling that "the ice sheet is warming, not only from the surface but internally as well," noted **Lora Koenig** [National Snow and Ice Data Center—*Research Scientist*].

The Mesmerizing View of Christmas Lights from Space, December 16; *The Washington Post*. The holiday spirit can now be quantified and measured—as a brightening of nighttime lighting so distinctive that, if you have the right technology to observe it, is visible from space. Such is the upshot of a new series of powerful NASA satellite-based composite images. The images are based on data from the Suomi National Polar-orbiting Partnership (NPP) satellite, whose Visible Infrared Imaging Radiometer Suite (VIIRS) is capable of viewing the side of the Earth that is facing away from the sun. The work was led by physicist **Miguel Román** [GSFC—*Research Physical Scientist*] and **Eleanor Stokes** [Yale University—*NASA Fellow and Ph.D. Student*]. Overall, the researchers found that nighttime lighting increased between 20 and 50% in U.S. cities and suburbs during the Christmas period, and that suburbs tended to light up more than urban centers. The holiday light-up isn't just an American phenomenon. The researchers also observed dramatic lighting increases in predominantly Muslim cities celebrating Ramadan, a month of fasting that shifts its date each year due to its basis in the lunar Islamic calendar.

***NASA: 11 Trillion Gallons of Rain Still Needed to End California's Drought,** December 18; *CNN*. About 11 trillion gallons of rain, or nearly 17 million Olympic swimming pools full. That's how much water California needs to recover from its extreme drought—despite downpours that recently caused flooding and mudslides. NASA released a satellite data analysis of how much water the state's reserves lack. It's a lot—more than 14,000 times the amount of water it would take to fill the Dallas Cowboys' stadium, according to *CNN* calculations. "It takes years to get into a drought of this severity, and it will likely take many more big storms, and years, to crawl out of it," said **Jay Famiglietti** [JPL—*Senior Hydrologist*], who led the study. NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites measured fluctuations in Earth's gravitational field and the changing shape of the planet's surface to determine the drop in water reserves. It's the first calculation of its kind to determine the amount of water needed to break a drought, NASA said.

***Satellite Map Shows Evidence of a Dangerous Arctic Warming Feedback Loop,** December 18; *Wired.com*. One of the ways our planet manages its heat budget is by storing solar energy in the ocean. In recent years, the Arctic has been taking in more than its usual share of heat energy, which could be bad news for our steadily warming planet. In the Arctic, the rate of heat absorption has increased by more than 10 W/m^2 since 2000. In some areas—like the Beaufort Sea north of Alaska—this rate has increased as much as 45 W/m^2. Not all of the sun's energy sticks around on Earth: Different land surface types bounce it back into space, while others absorb it. Ice, snow, and clouds are really reflective, and the reflectivity of water varies, depending on the angle of the sun. For the past 15 years, NASA has been using a satellite sensor called Clouds and the Earth's Radiant Energy System, (CERES) on three different satellites: Terra, Aqua, and Suomi NPP, to calculate how much solar energy is being absorbed versus bounced back into space.

NASA Satellites Show Dramatic Changes Along the Colorado River, December 18; *The Weather Channel*. Earlier this year a "pulse" of 105,000 acre-feet of Colorado River water was released from the Morelos Dam on the Arizona/Mexico border in an international effort to study the environmental impact of restoring the flow of the river to its historic reach into the Sea of Cortez. Due to water demand and allocation, the Colorado River—considered the most endangered waterway in the U.S.—hadn't reached the Sea of Cortez in 15 years, leaving the once lush delta a dry, barren mess. But the first of five pulses of water over the next five years appears to have had a dramatic and positive effect on vegetation along the banks of the river. As a new NASA/U.S. Geological Survey study found, the pulse caused a 23% increase in greenness from August 2013 to August 2014 along the stretch of the formally dry river. Those measurements were based on satellite observations from Landsat and MODIS.

***NASA Satellite's First CO_2 Maps of Earth Revealed,** December 18; *LiveScience.com*. This past summer, NASA launched its first satellite devoted to measuring atmospheric CO_2, a heat-trapping gas that is driving global warming. On December 18, 2014, NASA scientists unveiled the first carbon maps obtained by the spacecraft, named the Orbiting Carbon Observatory-2 (OCO-2). While the mission only started collecting its first scientifically useful information at the end of September, the initial results "are quite amazing," said **Annmarie Eldering** [JPL—*OCO-2 Deputy Project Scientist*]. As OCO-2 collects more data, the scientists are hoping to compile the most complete picture to date of how CO_2 is distributed, geographically and seasonally. They'll also look at the places where that CO_2 is removed—so-called *carbon sinks*. "We feel certain that once we have a larger dataset with this kind of density and precision, it will really be valuable to the scientific community to understand the carbon dioxide fluxes," Eldering said.

*See news story in this issue.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact ***Patrick Lynch*** *on NASA's Earth Science News Team at* ***patrick.lynch@nasa.gov*** *and let him know of upcoming journal articles, new satellite images, or conference presentations that you think would be of interest to the readership of* ***The Earth Observer****.* ■

NASA Science Mission Directorate – Science Education and Public Outreach Update

Theresa Schwerin, Institute for Global Environmental Strategies, theresa_schwerin@strategies.org
Morgan Woroner, Institute for Global Environmental Strategies, morgan_woroner@strategies.org

"The Ocean" Quiz from NASA's *Know Your Earth Project* Is Now Live

The new quiz called "The Ocean" from NASA's *Know Your Earth Project* is now available online at *climate.nasa.gov/quizzes/ocean-quiz*. The *Know Your Earth* Project aligns with the larger NASA *Earth Right Now* Campaign through quizzes related to NASA's Earth science activities; to date, eight quizzes have been released. The results of each quiz can be shared on social media pages.

To view the complete collection of quizzes visit *www.nasa.gov/content/know-your-earth-2014/#.VFubIr5UGA0*.

GLOBE Train-the-Trainer Workshop

Date—April 20-25, 2015

Registration is now open for the GLOBE Train-the-Trainer Workshop, to be held April 20-25, 2015, in Rapid City, SD. This workshop is targeted to those who will be conducting GLOBE workshops and offering GLOBE professional development activities to inservice and preservice teachers. Participants who complete the workshop will be equipped to train teachers in a full suite of hydrology, atmosphere and climate, soil, Earth system, and land-cover protocols.

You can register online, at *www.globe.gov/events/workshops/workshop/34406*.

For more information about the workshop, contact Anne Lewis at *annelewis@sd-discovery.com*.

19th GLOBE Annual Partner Meeting

Date—July 20-24, 2015

Los Angeles, CA, has been selected as the location of the 2015 GLOBE Annual Partner Meeting. Reserve the dates for what promises to be the most exciting GLOBE gathering of 2015, bringing together GLOBE partners, scientists, sponsors, and student researchers. This year's theme will be *Strengths of a GLOBE-al Community of Scientists*. The meeting will take place July 20-24, 2015. GLOBE Working Groups will have the opportunity to meet at the same location a day before the meeting begins, on July 19, 2015.

For more details, visit *www.globe.gov/events/eventsdetail/globe/19th-annual-globe-partner-meeting*.

NASA Postdoctoral Fellowships

Deadline—March 1

The NASA Postdoctoral Program offers scientists and engineers unique opportunities to conduct research in space science, Earth science, aeronautics, exploration systems, lunar science, astrobiology, and astrophysics.

Awards: Annual stipends start at $53,500—with supplements for specific degree fields and high cost-of-living areas. There is an annual travel budget of $8000, a relocation allowance, and financial supplement for health insurance purchased through the program. Approximately 90 fellowships are awarded annually.

Eligibility: An applicant must be a U.S. citizen, lawful permanent resident, or foreign national eligible for J-1 status as a research scholar to apply. Applicants must have completed a Ph.D. or equivalent degree before beginning the fellowship, but may apply while completing the degree requirements. Fellowships are available to recent or senior-level Ph.D. recipients.

Fellowship positions are offered at several NASA centers. To obtain more information and to apply for this exciting opportunity, visit: *nasa.orau.org/postdoc*. ■

EOS Science Calendar

April 20–24, 2015
4th NASA Carbon Cycle and Ecosystems Joint Science Workshop, College Park, MD.
cce.nasa.gov/cce/meetings.htm

April 21–24, 2015
Sounder Science Team Meeting, Pasadena, CA.

April 22–23, 2015
LCLUC Spring Science Team Meeting, College Park, MD.
lcluc.umd.edu/meetings.php?mid=61

May 5–7, 2015
CERES Science Team, Hampton, VA.
ceres.larc.nasa.gov/science-team-meetings2.php

May 19–22, 2015
Combined MODIS/VIIRS Science Team Meeting Silver Spring, MD

July 13–17, 2015
Precipitation Measurement Mission Science Team Meeting, Baltimore, MD.
By Invitation Only (Contact *Lisa.A.Nalborczyk@nasa.gov*)

September 21–23, 2015
GRACE Science Team Meeting, Austin, TX.
www.csr.utexas.edu/grace/GSTM

November 10–13, 2015
SORCE Sun-Climate Symposium, Savannah, GA.
go.nasa.gov/1zRx2Hj

Global Change Calendar

May 11–15, 2015
36th International Symposium on Remote Sensing of Environment, Berlin, Germany.
www.symposia.org

May 24–28, 2015
Japan Geophysical Union Meeting, Chiba, Japan.
www.jpgu.org/meeting_e

June 22–July 2, 2015
26th International Union of Geodesy and Geophysics, Prague, Czech Republic.
www.iugg2015prague.com

July 20–24, 2015
19th GLOBE Annual Partner Meeting, Los Angeles, CA.
www.globe.gov/events/eventsdetail/globe/19th-annual-globe-partner-meeting

July 26–31, 2015
IEEE International Geoscience and Remote Sensing Symposium, Milan, Italy.
www.igarss2015.org

August 2–7, 2015
12th Annual Asia Oceania Geosciences Society Meeting, Singapore, Japan.
www.asiaoceania.org/aogs2015

August 16–20, 2015
250th American Chemical Society National Meeting, Boston, MA.
www.acs.org/content/acs/en/meetings

announcement

Call for Nominations: The 2017 Decadal Survey for Earth Science and Applications from Space

In early 2015, the National Research Council (NRC) expects to appoint an *ad hoc* steering committee and a series of discipline and interdisciplinary study panels to carry out the second NRC decadal survey in Earth Science and Applications from Space, sponsored by NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey. This survey will generate consensus recommendations from the environmental monitoring and Earth science and applications community for an integrated approach to the conduct of the U.S. government's civilian space-based Earth-system science programs over a 10-year period commencing approximately at the start of fiscal year 2018 (October 1, 2017). The NRC now seeks nominations of individuals willing to volunteer their time to serve on the steering committee or study panels. Service is open to scientists, engineers, and other experts, with a broad range of relevant expertise—including those working for a government agency—provided they have relevant scientific and technical expertise needed to accomplish the committee's task and their service will not appear to compromise the independence and objectivity of the study. The NRC strives to appoint diverse committees and we welcome suggestions that might advance this objective. To learn more about the Decadal Survey and to nominate individuals please visit *sgiz.mobi/s3/eb9c7ce75e78*.

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Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. Newsletter content is due on the weekday closest to the 15th of the month preceding the publication—e.g., December 15 for the January–February issue; February 15 for March–April, and so on.

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